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SERIE: PLANKTON · BIND I

Nr. 8. Ove Paulsen: PLANKTON INVESTIGATIONS IN THE WATERS ROUND ICELAND AND IN THE NORTH ATLANTIC IN 1904. WITH 9 FIGURES IN THE TEXT

KØBENHAVN
I KOMMISSION HOS C. A. REITZEL
BIANCO LUNOS BOGTRYKKERI
1909

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IN THE WATERS ROUND ICELAND AND IN THE NORTH ATLANTIC IN 1904

BY

OVE PAULSEN

WITH 9 FIGURES IN THE TEXT

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INTRODUCTION.

The work now published mainly gives the results of my studies on board the "Thor", the Danish investigation-steamer, in 1904 and during the first half of the summer of 1905. It is a continuation of my work from 1904, which gave the results of my investigations in 1903.

This treatise is divided into two main parts, the first dealing mostly with the Microplankton, the second with the larger plankton-animals (Macroplankton). This division has been made for practical reasons, to facilitate the general view. But I also believe, that it is justifiable on account of the considerable difference in many biological conditions of these two groups of plankton — they might also be called plant plankton and animal plankton. The two groups are thus essentially different both with regard to vertical and horizontal distribution. The vertical distribution is different as the plant organisms can only live in the upper water-layers on account of their dependence on light, whilst it is known, that the animals undertake large vertical wanderings.

With regard to the horizontal distribution, it will be seen in the following, that the organisms of the microplankton are finer indicators than the animals and do not stand as many changes in the conditions of life as the latter. This regards perhaps the individual more than the species; it is seen namely, that whilst e. g. many species of diatoms have been found on all the coasts of Iceland, it has not once been possible to find a group of plankton algæ which as such and in the living condition has drifted from the west coast of Iceland to the eastern, more variable part of the north coast. (That the connection between coasts is possibly maintained by means of spores or such like is quite a different question.) It has on the other hand been possible to determine such a transport of animal organisms, e. g. *Calanus finmarchicus, Limacina retroversa,* young fish (Schmidt 1904, 1909).

As the investigations from 1903 exclusively dealt with the microplankton, it is in fact only the first part of the present work, which is directly a continuation of these.

After a stay in Bergen in the spring of 1904, I was able to deal also with the larger animal organisms. There I met with Dr. H. H. Gran and Dr. D. Damas and I cannot be too grateful for the instruction and information received from these scientists. — The first result of my studies on plankton animals was a treatise on the copepod *Calanus finmarchicus* (Paulsen 1906). The rest is found here. I am conscious of its defectiveness, but I hope, it will serve as a basis for continued studies on the plankton animals, studies which, I hope, will not be long delayed.

I desire here to offer my best thanks to my shipmates Dr. Johs. Schmidt and cand. mag. J. N. Nielsen for our companionship onboard. It was of the best kind both in scientific and social respects. I am specially grateful to Dr. Schmidt for permission to use his journals from the cruises on the "Thor" in which I did not participate.

I also tender my thanks to Professor G. O. Sars and Dr. D. Damas for having kindly determined the copepods and medusæ for me.

A brief summary of the hydrography is given here to help those, who do not know the hydrographic conditions of the waters round Iceland and do not have access to the literature.

The warm Atlantic water moves slowly up towards the south coast of Iceland. A sharp boundary is found to the east at "Hornene" between this water and the cold water of the East Iceland Polar Current. To the west the Atlantic water streams round Reykjanes northwards along the west coast of Iceland (the Irminger Current). Off the north-western point of Iceland the Irminger Current branches off in two parts: one bends westwards, is forced southwards by the East Greenland Polar Current from the north and is partly mingled with this water (the "basin-water" of the Denmark Strait). The other branch of the Irminger Current bends eastwards and follows the north coast of Iceland. It is here mingled with cold polar water from the north; but it can however — at any rate sometimes — be traced still to the east of Lánganes in the East Iceland Polar Current (NIELSEN 1905).

It is thus seen that an anti-cyclonic movement of the water takes place round Iceland; it is however not continual but broken at the south-east point ("Hornene"). The water is warmest in the sea on the south coast and then — in general lines — on the west coast, the north coast and the east coast.

I. MICROPLANKTON.

The following is a continuation of the investigations I published in 1904. The material has been collected in the same way as in 1903, it originates from two sources:

1. My own collections from the "Thor". In 1904 the "Thor" spent the whole summer at Iceland and sailed thrice round the island. While I was in Bergen in April Dr. SCHMIDT kindly collected samples for me. In 1905 the "Thor" was only on the east and south coasts, later also on the north coast; but I was not onboard at that time.
2. Collections from the post-steamers the "Holar" and the "Skálholt" during their voyages round Iceland in 1904 and 1905. The S. S. "Holar" sailed round the east of Iceland; its stations were the following: Vestmannaeyar, Hrolaugseyar, Papey, Lánganes, Rödehuk, Gogurtá. The S. S. "Skálholt" sailed round the west of the island and fished plankton at the following stations: Snæfellsnæs, Staalbjærg Huk, Isa Fjord, Cape North, Skagatá. The method used for the collections was to draw up the water by means of the deck-pump and filter it through a net of gauze 20.
3. The collections were made in the same manner from the S. S. "Laura", the post-steamer between Copenhagen and Reykjavik. From the "Laura" plankton has been gathered between Fair Isle and Reykjavik on 8 voyages in 1904.
4. The Greenland Steamer "Godthaab" has likewise collected plankton but only on three voyages, of which the two first were between Fair Isle and Cape Farvel, whilst the last one (in August) went to Angmassalik on the east coast of Greenland, thus across the Denmark Strait.

The treatment of the microplankton is divided into the following parts:

A. The south coast of Iceland.
B. The west coast of Iceland.
C. The north coast of Iceland.
D. The east coast of Iceland.
E. The distribution of the various species in the neritic plankton.
F. The oceanic plankton round Iceland and in the Northern Atlantic.

A. The south coast of Iceland.

Asterionella plankton is found along the south coast of Iceland from the end of April (before that time no samples occur), during May and June and a part of July. *Asterionella japonica* does not appear in some of the earliest samples, but the plankton organisms which occur are for the rest the same. This holds for samples from the "Holar" from Hrolaugseyar on the 17th of April and the 6th of May and from Vestmannaeyar on the 8th of May. On the other hand I have — when onboard the "Thor" — found a plankton rich in *Asterionella* at Ingolf's Höfde on the 27th of April.

Both in 1904 and 1905 *Asterionella* disappeared during the last half of July at Hrolaugseyar and Vestmannaeyar. Apparently it is present however during the whole summer round Vestmannaeyar, between these islands and the land. In the last days of July I found it still here in some hauls but not in others, and in 1905 it was found in the samples from the "Holar" singly until as late as the 27th of September.

With regard to the composition of the *Asterionella* plankton, it varies with the season. *Biddulphia aurita* is very common during the spring but completely disappears or almost completely with the end of the month of May. *Skeletonema costatum*, *Chaetoceras atlanticum* and *Ch. teres* also occur here during spring. *Thalassiosira gravida* and to a smaller extent *Th. Nordenskiöldii* seem to be more constant in this plankton group, but it may happen that they are lacking. *Chaetoceras decipiens, debile* and *diadema* are almost always found, *Ch. constrictum* and *Nitzschia seriata* mostly in June—July. In the beginning of June 1904 *Rhizosolenia semispina* occurred rather suddenly both at Vestmannaeyar and Hrolangseyar, but soon disappeared again.

With regard to the rest of the organisms of this group reference may be made to papers by Ostenfeld and by myself from 1904. The contents of a sample gathered at Vestmannaeyar on the 18th of May 1904 may be given as an example of the composition of the South Icelandic *Asterionella* plankton: *Asterionella japonica* c, *Biddulphia aurita* +, *Cerataulina Bergonii* r, *Chaetoceras atlanticum* +, *Ch. contortum* r, *Ch. debile* cc, *Ch. decipiens* cc, *Ch. Diadema* +, *Ch. laciniosum* +, *Ch. simile* rr, *Ch. teres* +, *Coscinosira polychorda* +, *Lauderia glacialis* r, *Nitzschia seriata* rr, *Skeletonema costatum* c, *Thalassiosira gravida* cc, *Thalassiothrix nitzschioides* r, *Cyttarocylis denticulata* +.

Halosphaera viridis was found off Ingolf's Höfde at station 112 at the end of May; at that period it was distributed over the whole sea between Iceland and the large fish-banks south-west of the Færoes.

Of the macroplankton organisms, which are found together with the *Asterionella* plankton, *Calanus finmarchicus* is the most common. I have already written about its distribution and biology.

Other copepods found here are:

Pseudocalanus elongatus, Oithona similis, Metridia sp., Acartia longiremis, Temora longicornis, Microsetella atlantica. Euchaeta norvegica but rarely occurs and then not at the surface. Of other *Crustaceæ* I have found *Thysanoëssa longicaudata, Boreophausia inermis* and *Nyctiphanes norvegicus* in a depth of ca. 20—50 M. off Reyknanes and *Podon sp.* at Reykjavik.

Limacina retroversa and *Clione limacina* as well as *Chaetognathidæ* can also be found in the region of the *Asterionella*, and the same holds for several medusæ.

Lastly, fish eggs are extremely common in the *Asterionella* plankton during spring; their constant presence at this time south of Iceland was first noted by Ostenfeld (1900) and later by Schmidt.

The larger plankton organisms do not seem to be dependent on the conditions necessary for the presence of the *Asterionella* plankton, they occur as well outside as together with the latter; it may even be stated that even if they are found there, they do not belong to it. Where the diatom plankton is dense, plankton animals are ordinarily lacking.

I have been able to investigate the distribution of the *Asterionella* plankton on the eastern part of the south coast at the end of May. At that period the "Thor" came from the south

towards Ingolfs Höfde. The oceanic plankton, which essentially consisted of *Chaetoceras* species (especially *Ch. decipiens* and *densum*, see below) extended northwards to about 63° 24′ N, 16° W, and here it was rather suddenly replaced by the coastal plankton with *Asterionella*, which afterwards extended to Ingolfs Höfde and had a breadth here of ca. 32 miles.

Some days later the eastern limit of the *Asterionella* plankton was found to be about midway between Eystra and Vestra Horn.

In 1905 the southern limit of the neritic plankton was in the end of May at the same place as in 1904, but the eastern limit was farther eastwards namely north-east of Eystrahorn between the latter and Seley.

At the western part of the south coast the distribution of the coastal plankton was investigated at the beginning of July. It occurred round Reykjanes in a breadth of at least 10 miles. Somewhat farther eastwards, about off Eyrarbakki, the breadth was 11 miles, and the limit between the brown water of the coastal plankton and the *Dinoflagellate* water found outside (to the south) here appears as a distinct line visible even at a close distance, and as the two sorts of water united in long tongues, this line was not straight but somewhat irregular.

Farther eastwards the coastal plankton was broader at this season, off Portland its breadth was between 40 and 50 miles, as its southern boundary was in the neighbourhood of the station 184 at 62° 42′ N. Lat. and 18° 53′ W. Long. The eastern boundary of the *Asterionella* plankton was in the middle of July a little west of Vestra Horn, thus more westerly than in the month of May.

The hydrographic conditions in the water of the *Asterionella* plankton. The rule seems to be, that the water, in which the *Asterionella* Plankton floats, is less saline than the water outside. It is indeed natural, that the salinity of the coastal water is lower than that of the water in open sea; but it is however worth stating, that the transition between the two sorts of water is coincident with the transition between the oceanic and the neritic plankton.

Off Ingolf's Höfde in the month of May the temperature and the salinity of the water was as given below:

Date	N. Lat.	W. Long.	Temp. C°	Salinity ‰	
24. V 11 p. m.	63° 51′	16° 25′	7·39	34·95	Neritic *Asterionella*-plankton
— 9·40 p. m.	63° 44′	16° 25′	7·49	35·01	
— 8·45 p. m.	63° 39′	16° 20′	7·72	35·01*)	
— 7·30 p. m.	63° 35′	16° 11′	7·79	35·11	
— 6·00 p. m.	63° 31′	16° 06′	8·00	35·16	
— 4·40 p. m.	63° 26′	16° 00′	8·04	35·19	
— 4·00 p. m.	63° 22′	15° 52′	8·20	35·24**)	Oceanic *Chaetoceras*-plankton
— 1·15 p. m.	63° 19′	15° 45′	8·15	35·25	
— 12·15 p. m.	63° 14′	15° 36′	8·02	35·23	
— 8·30 a. m.	63° 05′	15° 28′	8·19	35·25	

*) Station 114. **) Station 111.

To illustrate the conditions in the deeper water-layers, the temperature and salinity of two stations are given here, one outside and one inside the boundary of the coastal plankton.

	Station 111 Oceanic plankton		Station 114 Neritic plankton	
	Temp. C°	Salinity ‰	Temp. C°	Salinity ‰
1000 M.	4·70	35·10	...	...
750 -	6·06	35·16	...	...
400 -	7·55	35·23	...	...
100 -	7·86	35·23	7·19	35·16
25 -	7·89	35·23	7·46	35·07
10 -	...	...	7·41	35·03
0 -	8·20	35·24	7·72	35·01

It is seen, that down to a depth of 100 M. the salinity is less in the region of the coastal plankton. The hydrographic stations mentioned below (see map fig. 1) prove, however, that the coastal plankton is not necessarily dependent on low salinity.

	Stat. 175 63° 32′ N. Lat., 21° 30′ W. L. July 8th 10 a. m. Ca. 20 miles from land Depth: 106 M. Oceanic *Dinoflagellate*-plankton in the surface and deep water		Stat. 184 62° 42′ N. Lat., 18° 53′ W. L. July 11th 11 p. m. Ca. 42 miles from land Depth: 1340 M. Neritic *Asterionella*-plankton in the surface water (near its southern limit)		Stat. 185 63° 16′ N. Lat., 19° 17′ W. L. July 12th 6 a. m. Ca. 10 miles from land Depth: 765 M. Neritic *Asterionella*-plankton in the surface water	
	Temp. (C°)	Salinity (‰)	Temp. (C°)	Salinity (‰)	Temp. (C°)	Salinity (‰)
1300 M.	...	...	4·31	35·07		
1000 -	...	...	5·08	35·08		
850 -	...	...	5·88	35·13		
700 -	...	...	...	...	7·30	35·21
600 -	...	...	...	...	7·30	35·21
400 -	...	...	7·30	35·19	7·53	35·21
200 -	...	...	...	...	7·67	35·21
100 -	7·85	35·16	7·80	35·19	7·77	35·21
75 -	7·88	35·16	...	...	...	...
50 -	8·06	35·14	8·80	35·19	8·14	35·21
35 -	8·71	35·14	...	...	9·13	35·16·5
25 -	9·77	35·14	...	...	10·09	35·14
10 -	10·52	35·14	...	...	...	...
0 -	10·89	35·14	11·25	35·13	11·43	35·03

This proves firstly, that the oceanic plankton can approach close to the coast and that the salinity in this case is the same at the surface as in deep water, and secondly, that the coastal plankton can extend far out, but that the salinity in that case increases from the surface downwards. In other words, the reason why the *Asterionella* plankton has been found at station 184, is because fresher surface-water has been driven from the coast southwards. This also accords with the fact, that the plankton on station 184 was poorer in individuals than that from the following stations nearer the coast and poorer both in *Asterionella* and in *Leptocylindrus danicus* and *Nitzschia seriata* — the two first especially are typically neritic — whilst it was richer in *Peridinium ovatum*, which at least here and at this period was oceanic.

More singular than that the *Asterionella* plankton sometimes drifts out to sea southwards is the fact that it is also sometimes driven eastwards. On the seasonal cruise in 1905 I found a considerable quantity of *Asterionella* together with especially *Thalassiosira* at station Da 15, N. Lat. 64° 12′, W. L. 11° 45′. In a smaller quantity it was found at the more southern and eastern stations: Da 14, 63° 43′ N., 11° 45′ W., Da 12, 63° 40′ N., 10° 38′ W., Da 9, 63° 50′ N., 9° 00′ W., Da 3, 63° 06′ N., 6° 20′ W. — Further, the "Michael Sars" in 1900 (see Gran 1902, p. 133) found the same organism at the following places: 64° 46′ N., 10° 14′ W. ("nicht selten") and 63° 53′ N., 7° 15′ W. ("spärlich"). Besides with others it was found together with *Thalassiosira Nordenskiöldii, Chaetoceras cinctum* and *debile, Cerataulina Bergonii* and several of the common organisms from the *Asterionella* plankton. Gran also remarks that the surface-plankton at these stations is Icelandic summer-plankton (the *Asterionella* plankton), whilst in deeper water-layers it was arctic.

All the places mentioned are to the east of Iceland, and as will be seen from the map (fig. 1) on which they are marked (the two Norwegian stations are indicated with N.), they are so situated, that a current which follows the south coast of Iceland eastwards must arrive at them. The two stations, where the quantity of the *Asterionella* found was great, namely the Norwegian station 10 (1900) and Da 14 (1905), lie in the continuation of the current, which, following the coast, bends to the north-east, whilst the others lie due eastwards.

If *Asterionella* at these places has come directly from the south coast of Iceland, which I consider the most likely, the current along the south coast of Iceland must at some period have gone eastwards and probably it has then advanced above the fresher water of the East Icelandic Polar current. This is confirmed by investigation of the hydrographic conditions, as will be shown below.

1. On the hydrographic chart (HJORT 1901) from the cruise of the "Michael Sars" in 1900 tongues of salter water are seen just round the two stations (19 and 10), where *Asterionella* was found. The most northern, that at station 10, where the *Asterionella* was most numerous, comes from the west from the waters south of Iceland.

2. From NIELSEN's paper of 1904 we learn (p. 25) that just at the stations Da 14—Da 16 there was found salter water than at places south and north of these stations, and that this salter water can only have come from the west. Also in 1903 *Asterionella* was found here at the stations 12 and 14 — however in small quantity.

And in his 1908 paper NIELSEN states, "that the warm Atlantic water on the S. E.-coast must move in a N. E. direction parallel with the coast".

We cannot exclude the possibility, that the *Asterionella*, found at the places mentioned, may have passed round the north of Iceland, carried by the Irminger Current. But as *Asterionella* has very rarely been found on the north coast[1], the probability is but small. The discovery of a young sandeel in May 1905 at station Da 13 (63° 10′ N., 11° 45′ W.) is also evidence against this, as the sandeel does not spawn on East Iceland.

I have mentioned this matter in such detail, because it might be of some hydrographic interest to elucidate a disputed direction of a current from the side of the plankton.

I may now briefly outline the distribution of *Asterionella japonica* in other seas.

1. It has never been found at the Færoes. OSTENFELD (1903), does not mention it, nor have I ever observed it there, through I many times investigated the coastal plankton at the Færoes over a period of 3 years. This plankton is something special: *Thalassiosira bioculata* is here a predominant form.

2. It is rare along the west coast of Norway (JØRGENSEN 1899, 1905, GRAN 1900, 1902, HJORT and GRAN 1899). In all these papers it is mentioned but once: by JØRGENSEN in 1899 as very rare.

3. In the North Sea it occurs in masses in Helgoland Bay during spring (APSTEIN 1908). It is also a common spring form in the southern North Sea but may also occur at other times and with sudden maxima. In the remaining part of the North Sea it has, according to the Bulletin, sometimes been fished mostly in spring, but apparently it does not occur in the same manner in different years.

4. In the Skager Rak and Kattegat it is rare.

5. In the western part of the Channel it is found the whole year round.

6. According to CLEVE (1900, 1902) it is also known in the Antartic seas, at Japan and the Azores. PAVILLARD (1905) mentions it from a lagoon on the coast of the French Mediterranean. It is here a winter form as at Naples, where I have fished it myself.

It seems to me, that the distribution of *Asterionella* in the North Sea and in the Northern Atlantic is specially interesting. We have here an example of a neritic plankton organism which could be carried far by the currents in the sea, but which however is lacking at the Faeroes and at Norway where it might have been expected. I believe, that we may conclude from this that the sea-currents only have any importance for the transport of the microplankton organisms within limited areas as a rule, and that the groups of neritic plankton are not exchanged from coast to coast ("inflow of diatoms" JØRGENSEN 1905 p. 87) but are endogenetic and occur independent of each other.

As mentioned in my work of 1904 the *Asterionella* plankton on the south coast of Iceland is

[1] GRAN (1902) in Fig. 5 figures an "*Asterionella*-Region" lying North of Iceland. This is not correct. Nor can it be seen that *Asterionella* has been found in greater quantities on his own stations North of Iceland (Fig. 6 p. 128, 134 f.).

regularly, when the first part of the summer has gone (in July), replaced by a Dinoflagellate plankton, in which *Ceratium longipes*, *C. fusus* and *Peridinium ovatum* are predominant ("Longipes-Plankton", Ostenfeld). Sometimes also *Ceratium furca, tripos* and *lineatum* appear in considerable numbers. It is no real neritic plankton, as it mostly extends seaward without any change. It is however, as has been stated before, sometimes mingled with neritic diatoms; I have also noted above (p. 5), that *Asterionella japonica* can keep living round Vestmannaeyar until late in the summer. I have for the rest not very much to add about the South Icelandic summer plankton. Regarding the distribution of the Ceratium species reference may be made to the part which deals with West Iceland.

A feebler second diatom maximum seems however constantly to appear in September—October; it consists especially of *Chaetoceras decipiens* which is certainly known to occur the whole summer but during the months mentioned it reproduces abundantly. Together with this group several more irregularly appearing species occur: *Coscinodiscus sp., Chaetoceras debile, diadema, laciniosum, scolopendra, Rhizosolenia styliformis, Thalassiothrix nitzschioides* and *longissima, Dactyliosolen antarcticus, Corethron criophilus.* Their appearance is very varying. A maximum has been stated in both years, as also in 1903 (Paulsen 1904, Table I) and in 1899 (Ostenfeld 1900).

After the disappearance of the *Asterionella* plankton the water becomes richer in macroplankton organisms. It is specially striking in the "Holar's" samples from Vestmannaeyar and Hrolaugseyar, that small copepods are mostly found after the disappearance of the *Asterionella* plankton. I have noted the following species: *Acartia longiremis, Microsetella atlantica, Oithona similis, Temora longicornis, Nauplius.* Together with these *Calanus finmarchicus* has often been found. — These organisms have been found close to the beach. As the limit between the neritic and the oceanic plankton is not sharp in late summer, I may, with regard to the rest of the animals in the macroplankton, refer to the later pages.

B. The west coast of Iceland.

Of material from this coast I have collections from the steamer "Skálholt" in 1904 and 1905 and my own observations from 1904; in addition to these a series of samples gathered in the roads of Reykjavik by Mr. Bjarni Sæmundsson.

The positions of the "Skálholt's" collections are: Snæfellsnes, Staalbjerg Huk (Bjargtangar) and Isa Fjord. I may briefly describe the character and changes of the plankton at the places mentioned in the summers of 1904 and 1905, beginning with the southernmost and continuing northwards.

Reykjavik. The collections took place every fourteenth day from the 12th of March to 13th of July 1904 and further — with some few interruptions — from the first of November 1904 to the 16th of March 1905.

Thalassiosira gravida and *Nordenskiöldii* are predominant in the plankton until the middle of June; of their companions the following may be noted: in early spring *Biddulphia aurita, Lauderia glacialis, Skeletonema costatum*, in May-June *Chaetoceras debile, diadema, furcellatum, teres, Coscinosira polychorda, Phaeocystis Pouchetii.*

In the sample from the 10th of June there was *Asterionella* plankton with *Asterionella, Cerataulina Bergonii, Chaetoceros constrictum, contortum, convolutum, decipiens, Nitzschia seriata* besides many of the May forms formerly mentioned.

At the end of June *Leptocylindrus danicus* and *Nitzschia seriata* are predominant, the Dinoflagellates also now begin to appear: especially *Dinophysis acuminata* and several *Peridinium*-species, however, still few in number. The last summer sample (July 13) contains Dinoflagellate plankton: *Ceratium lineatum,*

fusus and *longipes*. *Dinophysis norvegica* and *Peridinium conicum* are found, and besides *Amphorella subulata*, *Cyttarocylis denticulata*, *Tintinnopsis karajacensis var. acuta*, *Rhizosolenia setigera* and *Skeletonema costatum*. The autumn and winter samples present indicate a plankton very poor in *Coscinodiscus* and *Biddulphia aurita* and also Tintinnids. Of the last mentioned *Codonella ventricosa*, *Cyttarocylis denticulata* and *gigantea* are found.

Snæfellsnes. The samples have been gathered on the following days: in 1904 on the 16th of April, the 9th and 15th of May, the 3d and 10th of June, the 14th and 23th of July, 21st and 25th of August, 18th and 27th of September, the 10th of November, in 1905 the 9th of May, the 3d and 10th of June, 13th and 24th of July, 21st and 26th of August, 19th and 27th of September, the 1st of November.

The *Thalassiosira* plankton of spring continues in both years through a part of June. *Biddulphia aurita* is an early form of the accompanying organisms, whilst *Chaetoceras debile, decipiens* and *diadema* (and others) occur somewhat uniformly during the whole time. *Lauderia glacialis* has been found in 1904, but not in 1905. It is most likely, that *Codonella ventricosa, Tintinnopsis karajacensis var. acuta,* Cirripede larvæ also belong to the *Thalassiosira* plankton. It also contains *Peridinium ovatum* almost regularly. From both the years — 1904 and 1905 — one sample with *Asterionella* plankton is present. In 1904 it was taken the 2nd of June, in 1905 the 9th of May. These two samples are distinguished among the others also by the presence of species which are otherwise lacking: *Chaetoceras contortum, furcellatum, laciniosum, Peridinium conicoides.*

After the *Thalassiosira* plankton follows the Dinoflagellate plankton. *Ceratium lineatum, longipes, fusus* occur numerously in this plankton, whilst *C. furca* and *intermedium* are but few, and *C. tripos* does not appear before August—September and only in single specimens. Of other Dinoflagellates now appear: *Dinophysis norvegica* and *acuminata, Peridinium depressum, conicum, færoënse, pallidium* and *pellucidum,* whilst *P. ovatum* occurs more commonly than before. *Codonella ventricosa* and *Tintinnopsis karajacensis var. acuta,* which both mainly disappear with the diatoms are now replaced by *Amphorella subulata,* and further *Tintinnus acuminatus* and *Ptychocylis urnula* and *obtusa* are found, in smaller numbers however. Lastly the following organisms, which were rare or lacking in the diatom plankton, are found commonly in the Dinoflagellate plankton: *Dictyocha speculum, Nauplius, Oithona similis, Microsetella atlantica.*

In August—September 1905 a small, new diatom maximum appears, the organisms of which are mingled with the Dinoflagellates. It consist of the following species: *Rhizosolenia styliformis* is the most important, occurring from the 24th of July to the 27th of September (rr + + + r), and it is followed by *Coscinosira polychorda, Nitzschia seriata, Rhizosolenia Shrubsolei* and *R. setigera,* the last mentioned however only in small numbers (r) and in one sample (Septbr. 27th).

In the last three samples (from the 19th of Sept. to the 1st of November) there is found, with decreasing number of Dinoflagellates, constantly a small number of *Chaetoceras decipiens,* in some samples together with *Ch. laciniosum, Corethron criophilum, Thalassiothrix longissima* and species of *Coscinodiscus* especially *C. concinnus.* This is thus the end of the second diatom maximum, which begins with *Rhizosolenia styliformis.*

In 1904 this second diatom maximum is only indicated: *Thallassiothrix longissima* is the most constant here and is present in the three last samples (from the 18th of Septbr.). Only in the sample from the 27th of September rather small quantities of *Rhizosolenia setigera, Skeletonema costatum, Coscinodiscus radiatus* and *Biddulphia aurita* occur; as in 1905 the Dinoflagellates decrease and the *Coscinodisci* increase in the last samples.

Staalbjærg Huk. The samples have been gathered on the following days: in 1904 on the 17th of April, the 7th and 20th of May, the 2nd and 13th of June, 10th and 26th of July, 17th and 28th of August, 17th and 29th September, 6th of November and in 1905 the 7th and 18th of May, the 2nd and 14th of June, 11th and 27th of July, 17th and 28th of August, 19th and 29th of September, 31st of October.

As at Snæfellsnes the first diatom maximum continues during a part of the summer. *Thalassiosira gravida* and *Nordenskiöldii* are the main forms; together with these have been found *Biddulphia aurita*, *Detonula confervacea* (early, the last only in 1905), *Chaetoceras debile*, *Coscinosira polychorda*, *Lauderia glacialis* (only in 1904) and further the more scattered *Chaetoceras decipiens*, *diadema*, *laciniosum*, *simile*, Cirripede larvæ. In May and June some few of the samples from both years contain *Asterionella japonica*, especially in great number on the 14th of June 1905. Apparently the *Asterionella* samples also contain here peculiar species though in small numbers: *Chaetoceras convolutum* and *teres*, *Nitzschia seriata*.

The Dinoflagellate plankton is predominant from the first half of July at the same time as that at Snæfellsnes, and as at that place it is found a little earlier in 1904 than in 1905; in the former year it already begins to appear in the middle of June. The species and their frequency are the same as at Snæfellsnes. Chronologically the frequency of the Ceratii is the following: *Ceratium lineatum*, *longipes*, *fusus*, *intermedium*, *furca*, *tripos*. *C. furca* is quite lacking in 1905, and in 1904 it was not so numerous as at Snæfellsnes, and quite the same is the case with *C. tripos*, of which but few specimens occurred in two samples in 1904. Other Dinoflagellates present at this period are *Peridinium ovatum*, *depressum*, *pallidium*, *pellucidum*, *Dinophysis acuminata*, *Diplopsalis lenticula* (only few), and together with these the following animal organisms were found: *Amphorella subulata*, *Tintinnus acuminatus*, *Cyttarocylis denticulata* and *gigantea*, *Ptychocylis urnula* and *obtusa*, *Nauplius*, *Oithona similis*, *Pseudocalanus elongatus*, *Calanus finmarchicus*, *Acartia longiremis*.

A second diatom maximum, the organisms of which are mingled with the Dinoflagellates, has been found in 1904 in the sample from the 17th of September; the following common diatoms are present: *Thalassiothrix longissima*, *Chaetoceras curvisetum*, *debile*, *decipiens*, further also *Dictyocha speculum* and a series of rarer species, among others *Cerataulina Bergonii*, *Chaetoceras cinctum*, *laciniosum*, *peruvianum*, *Coscinodiscus*-species, *Nitzschia seriata*, *Rhizosolenia styliformis*. The sample before and the sample after this show slightly the beginning and the conclusion of this maximum, only *Thalassiothrix* and *Dictyocha* are rather frequent.

In 1905 on the 17th and 28th of August a feebler but somewhat similar maximum has been found with *Chaetoceras curvisetum*, *debile*, *Nitzschia seriata* and *Dictyocha speculum*, but in September (the 19th) the organisms have changed and it is now *Rhizosolenia setigera*, *Shrubsolei* and *styliformis*, which together with *Nitzschia seriata* are the dominating forms; *Coscinosira polychorda*, *Chaetoceras decipiens* and others are present in smaller numbers.

In the latest samples all organisms decrease, and some few *Coscinodisci* and *Biddulphia aurita* appear.

Isa Fjord. The samples have been gathered on the following days: in 1904 on the 20th of April, on the 5th, the 21st and 31st of May, the 16th of June, the 9th and 27th of July, the 15th and 31st of August, the 14th of September, the 4th of October, the 2nd of November and in 1905 on the 5th, 19th and 31st of May, the 7th and 16th of June, 13th and 30th of August, 15th of September, 4th and 28th of October. The orders were that they should be collected in the outer, open part of Isa Fjord, but it cannot be stated as certain, that this has always taken place. At any rate the samples have been collected in some more enclosed water than on the preceding stations.

The first diatom maximum consists as usual of *Thalassiosira gravida* and *Nordenskiöldii*; in a few of the samples *T. hyalina* is also found. Only in the earliest samples there is also found commonly: *Biddulphia aurita*, *Chaetoceras cinctum*, *sociale*, *pseudocrinitum* (1905), *Phaeocystis Pouchetii*. Both in these and in the later *Chaetoceras debile*, *diadema*, *furcellatum*, *cinctum*, *teres*, *Coscinosira polychorda*, *Fragilaria oceanica* (1904) are present. Only in the samples from June (in 1905) were *Chaetoceras constrictum*, *laciniosum*, *Rhizosolenia semispina* found. In 1905 after the middle of May some Dinoflagellates are present among the diatoms in small number but rather constantly, namely, *Peridinium conicoides*, *ovatum*, *pallidum*,

pellucidum. Together with these also *Ptychocylis obtusa*. In 1904 only a few specimens of some of these have been found.

Only in 1905 is there a sample which contains *Asterionella*, from the 16th of June. It is somewhat richer than the preceding samples, but contains almost the same organisms; in addition to *Asterionella* it only seems characterised by *Chaetoceras laciniosum*.

As far as can be seen the true Dinoflagellate maximum begins in both years about the first of July. *Ceratium lineatum, longipes* and less distinctly *C. fusus* are the most characteristic forms, in 1904 a single cell of *C. furca* and one of *tripos* was found in the beginning of October, in 1905 these species were not seen. Together with the Ceratii we find: *Peridinium ovatum, depressum, pellucidum, færoënse* (1905), *subinermis* (1904), *Dinophysis norvegica* and further in 1904 *Amphorella subulata, Cyttarocylis denticulata, Ptychocylis urnula* and *obtusa, Nauplius, Oithona similis, Acartia longiremis*. The occurence of all these was in 1905 very scattered and inconstant.

The Dinoflagellate maximum was in 1905 on the whole much feebler than in 1904, whilst the amount of the diatoms, both the early and the late, was the same.

We do not find the same conditions in Isa Fjord as at the former stations, that all the diatoms disappear, when the Dinoflagellate maximum begins.

Chaetoceras debile is the form characteristic at this station (comp. Paulsen 1904 p. 13), it is found in almost all samples in considerable number and only decreases in the last ones. On the other hand the *Thalassiosira* species disappear, when the Dinoflagellate period has begun and together with this the *Chaetoceras teres, cinctum, furcellatum*. The diatom flora continues however during the whole summer abundantly. *Coscinosira polychorda* does not disappear before August, and several diatoms occur, which were not found in the first maximum. *Chaetoceras curvisetum* and *Nitzschia seriata* are the most important of the diatoms in this second diatom maximum (Aug.—Sept.), besides these, *Rhizosolenia setigera, Chaetoceras laciniosum, decipiens* and *simile, Skeletonema costatum, Thalassiothrix longissima* and *nitzschioides, Leptocylindrus danicus, Dictyocha speculum* occur in both years though in varying number, and *Biddulphia aurita* likewise appears in small number in the last samples of both years. *Cerataulina Bergonii, Chaetoceras constrictum* and *Coscinodiscus radiatus* were only found in 1904 and in 1905 only *Chaetoceras gracile* and *simile, Rhizosolenia Shrubsolei* and *styliformis*.

These collections from the two years by the post-steamer on the west coast of Iceland show in general lines the variation of the plankton during the course of the summer. We may briefly summarise as follows:

1. The neritic plankton from spring and most of June inclusive is a *Thalassiosira* plankton, in which, besides the two species of the genus mentioned, the following seem to be constantly present: *Biddulphia aurita* (spring form), *Chaetoceras debile* and *diadema*.

2. On all stations some samples have been taken in May or June with typical *Asterionella* plankton; they occur, so to speak, as interruptions in the *Thalassiosira* plankton. This seems to show, that *Asterionella* and its companions have not their native places here, but have been carried hither by changing currents and in that case they must have come from the west from the *Asterionella* belt, which originates from the south coast of Iceland and is found west of Iceland outside the real neritic plankton (see below p. 14).

3. From about the beginning of July the Dinoflagellates are in the majority. *Ceratium lineatum, longipes* and *fusus* are everywhere the forms predominant; together with these we find *Peridinium ovatum, pallidum, pellucidum, faeroënse* and others, further *Amphorella subulata* and other Tintinnids, and lastly the Copepods do not become common before this time. Some few specimens of *Ceratium tripos* and *C. furca* are almost always found in a few samples in August—October.

4. In August—September a second and smaller diatom maximum appears, the organisms of which are mingled with the Dinoflagellates. The most important are *Rhizosolenia styliformis, setigera* and *Shrubsolei, Nitzschia seriata, Chaetoceras curvisetum* and *Thalassiothrix longissima*. *Dictyocha speculum* also seems to belong to this maximum.

5. In Isa Fjord, which is a more closed water than the others, the importance of the diatoms after the first maximum is greater than at the other stations.

6. In the latest samples *Biddulphia aurita* occurs again, often together with *Coscinodiscus*-species.

The results above can be supplemented by my observations onboard the "Thor" in 1904. In 1905 the "Thor" was not on the west coast.

From the 22nd of April a sample is present from Staalbjærg Huk; as might be expected it contains *Thalassiosira* with *Biddulphia* and *Coscinodiscus radiatus*, but it is surprising that it also contains considerable quantities of *Ceratium tripos*. This is a unique phenomenon; I am sorry, that I cannot elucidate it by further collections.

In the beginning of June the "Thor" came again to West Iceland and first stayed for some time on the north-west land. We may first discuss the plankton of the fjords.

Of these fjords Isa Fjord and Arnar Fjord are open fjords with many branches, whilst Oennundar Fjord, Dyra Fjord and Patriks Fjord are narrow fjords all partly closed by an "Øre" — a land-tongue across the direction of the fjord. Where no other information is given, the plankton has been fished inside the tongue.

Isa Fjord. June 2—13. The broad open fjord is filled with *Thalassiosira* plankton with *Chaetoceras furcellatum, Nitzschia seriata* etc.

Oenundar Fjord. June 5. At the mouth the same plankton was found with rather few *Phaeocystis Pouchetii*, and in the fjord again the same, but here mingled with quantities of *Diplopsalis lenticula, Peridinium conicoides* and *Tintinnopsis karajacensis var. acuta*.

Dyra Fjord. June 13. Few *Thalassiosira gravida*, more *Th. Nordenskiöldii* and *Chaetoceras criophilum*. Great quantities of *Goniodoma Ostenfeldii*; further, several *Peridinium pellucidum, Heterocapsa triquetra, Tintinnopsis karajacensis var. acuta, Nauplius, Acartia longiremis*. — The greater part of these Dinoflagellates and Tintinnids were found at the mouth of Dyra Fjord, also *Phaeocystis, Chaetoceras convolutum* and *laciniosum, Coscinosira polychorda* and *Thalassiosira gravida*, all in small numbers.

Arnar Fjord. June 16—17. At the mouth many *Phaeocystis Pouchetii*, but few *Thalassiosira gravida* and other diatoms (*Chaetoceras decipiens*), the greater part in the surface-waters. At a depth of 57—40 M. (from the bottom) none, but at the surface great quantities of *Goniodoma Ostenfeldii*. — *Peridinium ovatum* both in surface and deep water, *Gonyaulax spinifera* occurred almost at the first one.

In one of the branches of this large fjord there was found of diatoms several *Fragilaria oceanica* and *Chaetoceras convolutum*, of other organisms many *Gonyaulax spinifera, Goniodoma Ostenfeldii, Peridinium ovatum* and *pellucidum, Ptychocylis obtusa, Tintinnopsis karajacensis var. acuta*.

Patriks Fjord. June 25. No diatoms. Many *Peridinium pellucidum* and *ovatum, Goniodoma Ostenfeldii, Diplopsalis lenticula*.

In the sea outside the fjords of the North-West Land, the end of June is, as we know from the collections of the "Skálholt", the period when the transition from the first diatom maximum to the Dinoflagellate maximum occurs. In agreement with this we find, that *Thalassiosira* is not very common here, and in some samples it is lacking. Thus, a sample, taken at Staalbjærg Huk on the 26th of June, had the composition: many *Chaetoceras debile, laciniosum* and *teres, Heterocapsa triquetra, Goniodoma Ostenfeldii,*

Peridinium ovatum, Cyttarocylis denticulata and *Ptychocylis obtusa*, few *Chaetoceras decipiens, Peridinium conicum, pellucidum, Tintinnopsis karajacensis var. acuta, Nauplius*. On the same day a very poor sample was taken close by at Straumnes, it contained amongst others few *Rhizosolenia semispina*. The species last mentioned no doubt originates from the oceanic plankton of the Denmark Strait, whilst most of the Dinoflagellates at Staalbjærg Huk must originate from the fjords close by, where they were found in great number, as shown by the list given above.

The plankton here thus seems to consist of three elements:

1. The neritic coastal plankton. Its most important form is *Phaeocystis Pouchetii*, which is ordinarily lacking in the fjords, *Chaetoceras laciniosum* and *decipiens* are less important. *Thalassiosira* may occur but is on the decrease.

2. The fjord plankton which is carried out from the fjords by the surface current. It especially consists of Dinoflagellates: *Goniodoma Ostenfeldii, Diplopsalis lenticula, Heterocapsa triquetra, Peridinium conicoides* and *pellucidum* etc. *Tintinnopsis karajacensis var. acuta* also belongs to this plankton. It is shown above, that each of the fjords has its own plankton, *Thalassiosira Nordenskiöldii* and *gravida* are very common in most of them. I suppose, they are here a sort of remnant from the first diatom maximum. The relation between a fjord and the water outside may be namely that when the fresher surface-water is carried out of the fjord, water must be sucked into the fjord from the deeper water-layers outside, and with this current the sea-plankton (in this case the neritic) must be brought in, and if possible, it will develop further in the fjord. This has probably happened with *Thalassiosira*.

3. The third element is the oceanic, only represented here by *Rhizosolenia semispina*.

From the North-West Land the "Thor" went in 1904 westwards out into the Denmark Strait, returned again to the North-West Land and thence southwards past Snæfellsnæs to Reykjavik. This voyage gave good information on the distribution of the *Asterionella* plankton west of Iceland.

The stations next to the North-West Land have been mentioned above; no *Asterionella* was found there. It occurred from about 65° 64′ N., 24° 37′ W. westwards in great number, and as can be seen from chart fig. 1, on which its distribution is outlined, it was found westwards until past the stations 150 and 155, consequently in a belt, the breadth of which was ca. 50 miles. This belt was thus found outside (west of) the true coastal plankton of West Iceland. Together with it there were found here *Chaetoceras debile, decipiens* and *diadema, Nitzschia seriata, Thalassiosira gravida* and *Nordenskiöldii*, in smaller number *Chaetoceras laciniosum* and *furcellatum, Phaeocystis Pouchetii, Goniodoma Ostenfeldii, Peridinium pellucidum*. The extent of the *Asterionella*-belt is just the same as that of the coastal water westwards (Nielsen 1905 p. 16).

All the latter, except *Nitzschia seriata*, were lacking or rare west of the *Asterionella* belt; *Rhizosolenia semispina* and *alata* together with *Nitzschia seriata* were predominant here.

Together with these main forms in the oceanic plankton of the Denmark Strait the following occur, which were lacking or rare in the *Asterionella* plankton: *Chaetoceras convolutum, boreale, atlanticum, Thalassiothrix longissima, Coccolithophora pelagica*. Of Dinoflagellates: *Gonyaulax spinifera* and *Peridinium pallidum* were sometimes found in not a small number, but they were not lacking either in the *Asterionella* plankton.

With regard to the distribution of the latter southwards, it was found in the end of June and the beginning of July in the western, outer parts of Brede Bay and Faxe Bay. But in the eastern part of Faxe Bay it has, strangely enough, not been found at the surface but in a depth of ca. 10—20 M.

The most predominant in the surface plankton were here Dinoflagellates, especially *Ceratium lineatum, Peridinium ovatum* and *pellucidum, Goniodoma Ostenfeldii* etc. and further some *Tintinnids: Cyttarocylis denticulata, Ptychocylis obtusa* and *Tintinnopsis karajacensis var. acuta*, and some diatoms: *Chaetoceras boreale, decipiens, laciniosum, Rhizosolenia alata* and *semispina*.

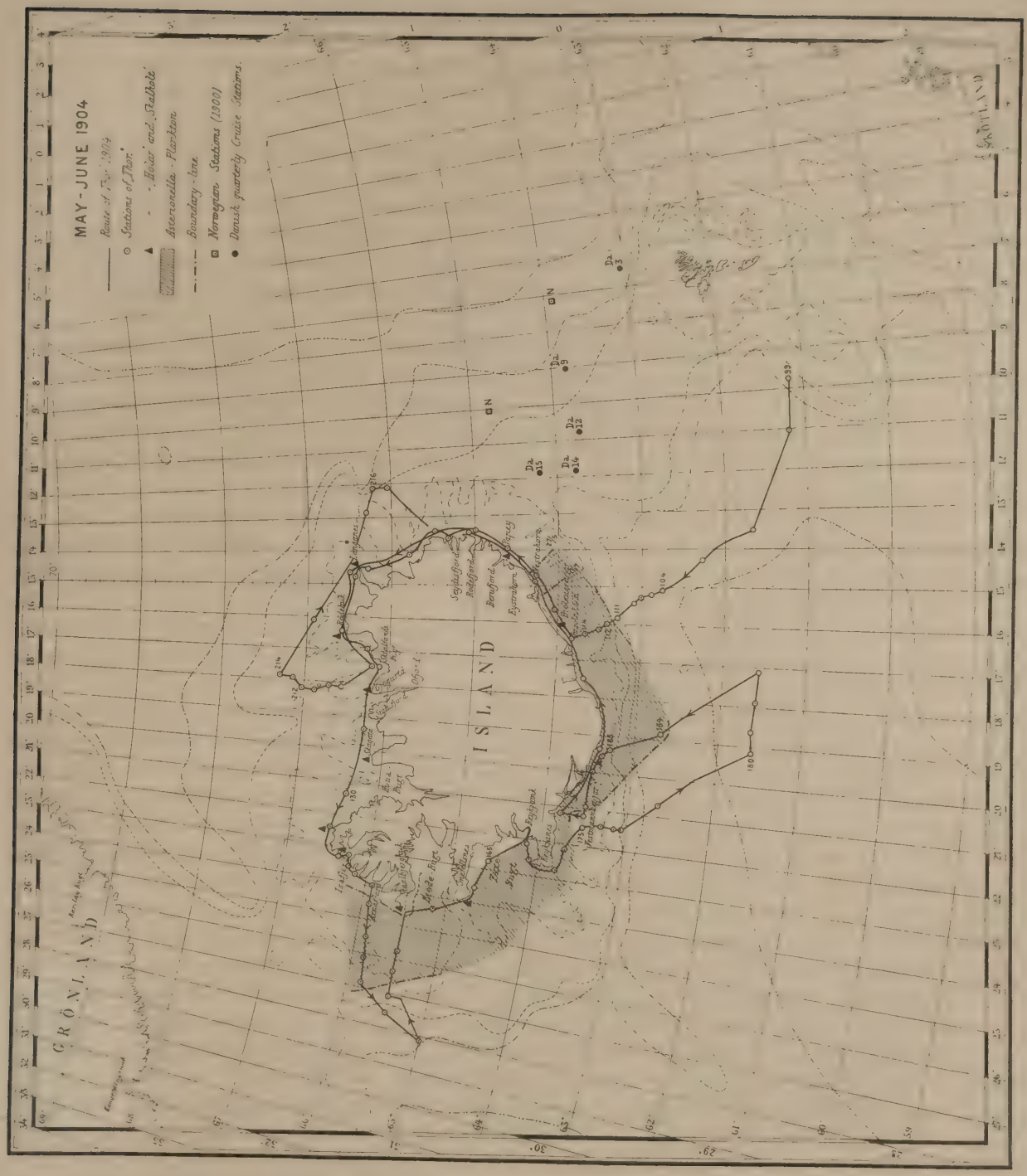
MAY-JUNE 1904
Route of Fox 1904
Stations of Fox
Hvidø and Fladholt
Intermediate Plankton
Boundary-line
Norwegian Stations (1900)
Danish quarterly Cruise Stations
GRØNLAND
ISLAND
SKOTLAND
Da 3
Da 9
Da 12
Da 14
Da 15
N

Fig. 1.

It is a remarkable condition here, that the neritic plankton was found under the oceanic surface plankton. As unfortunately none of the hydrographic stations were in this region, I am not able to give any hydrographic illustration or explanation. To examine if the wind could have any influence I have procured information on the direction and strength of the wind in Reykjavik during that period. But I do not think it gives any explanation, viz., that the wind from the 26th to the 29th of June was E. or S. E., very feeble, and from the 30th of June to the 9th of July mostly N. W., some few days E. or S. E., constantly very feeble, or none at all.

At the end of the month of August 1904 the "Thor" followed again the west coast of Iceland from the north. Except in the deep water of Isa Fjord, where as always many diatoms (*Chaetoceras debile, decipiens* etc.) were present, the Dinoflagellates were now predominant everywhere and of these again the *Ceratii*. The species of this genus were distributed in a peculiar way, which I have endeavoured to give on the chart fig. 2. The north and south coast are also given here to facilitate the general view.

Ceratium arcticum only occurs on the north coast and here in huge quantities; at this period it is not found in large quantities west of the Huna Bay.

Ceratium longipes is on the north coast the true companion of the preceding, but it extends much farther southwards; it is thus found in considerable quantities in the plankton along the west coast of Iceland and along the south coast until Vestmannaeyar. South and east of these islands it becomes rare. This species is like a radiation southwards from *C. arcticum*.

Ceratium tripos is only found in great numbers on the south coast; to the north of Skagi, the north point of the Reykjanes Peninsula, it only occurred in single specimens.

Ceratium lineatum is like a radiation northwards from *C. tripos*. Its southern limit of common occurrence is a little to the south of Skagi, about at Vestmannaeyar. Northwards it is common along the whole west coast and in the Huna Bay, where it has a very large maximum. It is only east of the Huna Bay, that it becomes mingled with *Ceratium arcticum*.

This relation between the distribution of *Ceratium tripos* and that of *C. lineatum* has a special signification in connection with the statement of Lohmann (1908), that these two species belong together, the one arising from the other by division.

The full connection is however not yet known; we do not know especially, how Lohmann's *f. truncata* comes into existence (by autotomy?, see Kofoid 1908), and it is this form, which by division produces f. *lineata* or *Ceratium lineatum*, by which name it is called here for the sake of convenience.

If we take it for granted, that *Ceratium tripos* by division produces *C. lineatum* — and doubts about this can hardly be raised, when Lohmann's investigations are considered — an interesting case is present here at Iceland. According to our discoveries here it is very probable, that *C. lineatum* requires other conditions of life than *C. tripos*; the latter occurred namely only on the west coast in single specimens, whilst the first is the most common Dinoflagellate here. The contrary is the case on the south coast where *Ceratium tripos* is predominant, whilst *C. lineatum* is everywhere rather rare except on the area between Vestmannaeyar and Reykjanes. This area, the only one where large quantities of both species are found together, thus seems to be the source whence the *Ceratium lineatum*-stream to the north originates.

Consequently, just at the limit between the south and west coasts, between Atlantic water and the Denmark Strait, which has its own rotation-current, just here *Ceratium tripos* terminates suddenly and changes into *C. lineatum* — always supposing that Lohmann's statement is right — which continues the life of the species in the colder water on the west coast. The following data from the Nautical-Meteorological Annual 1904 illustrate that the water is colder along the west coast than along the south coast: in the month of August the observed surface-temperature between Vestmannaeyar and Reykjanes varied from 11·3°—12·9°, whilst the corresponding temperatures are: in Faxe Bay 10·6°—12·°, in Brede Bay 9·9°—10·1°, in Isa Fjord 8·3°—9·5° and in Huna Bay 7·5°—8·3°.

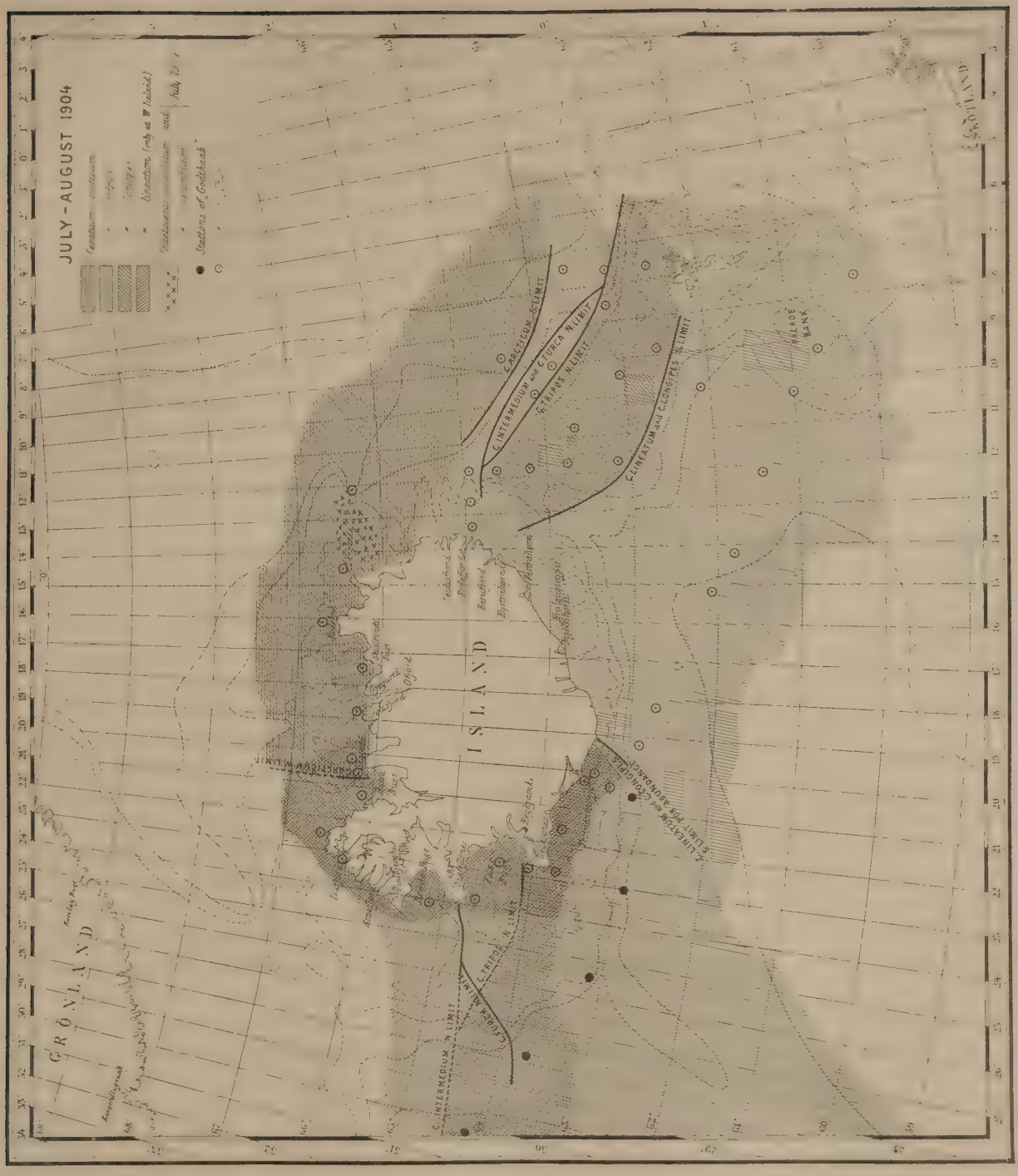
JULY - AUGUST 1904
Stations of Godthaab
GRÖNLAND
ISLAND
SCOTLAND
FAROE BANK
C. GRACILIS S. LIMIT
C. INTERMEDIUM and C. FURCA N. LIMIT
C. TRIPOS N. LIMIT
C. LINEATUM and C. LONGIPES S. LIMIT
C. LINEATUM and C. LONGIPES S. LIMIT FOR MAXIMUM ABUNDANCE
C. INTERMEDIUM N. LIMIT
C. FURCA N. LIMIT
C. TRIPOS N. LIMIT

Fig. 2.

In Huna Bay all specimens show a strange condition. Firstly the longitudinal furrow is dilated to such a degree, that the shell is almost quite without front, only the hypothecæ have two narrow stripes on the sides (fig. 3 a, c; fig. d is the only exception I have found). Further all specimens except the empty shells have a brownish sac with granular contents; it is fastened almost at the place of the flagellar pore (fig. 3 a, b). All or almost all the plasma contents are gathered in this sac, in a. some remnants are seen above it. A dark, oblong body is constantly found in the uppermost part of the sac; it has no structure in preserved material; perhaps it is the nucleus, which in that case must have diminished, as *Ceratium*-nuclei otherwise are very large. The whole picture is very much like ZEDERBAUER's drawings (1904) of *C. hirundinella* before copulation, and this would also accord with the supposition of LOHMANN, that *C. lineatum* is a copulating form of *C. tripos*. A fact, which at any rate is not unfavourable to the possibility, that we have here copulating individuals, is, that all specimens are thick-walled and much sculptured, consequently probably old, and that no newly divided individuals are present. In Faxe Bay many newly divided occurred, and all individuals were less sculptured and more thin-walled.

Fig. 3. *Ceratium lineatum* from Huna Bay, Aug. 23th 1904. Fig. c: an empty shell. 460 t. m.

I have not seen *C. tripos f. lata* and of *f. truncata* only some few individuals near Vestmanna islands; the latter had truncated but not shortened back-horns.

I regret that I have not examined the samples from this station except in a preserved state.

In the Denmark Strait the conditions with regard to *Ceratium lineatum* are similar. Fortunately I have in my possession a series of plankton samples, gathered by the S. S. "Godthaab" on its way to the East Greenland station Angmagsalik. The route passes ca. 50 miles to the south of Iceland and about in the direction W. N. W. The samples dealt with here, have been taken on the 26th—27th of August, thus on the same days when the "Thor" was at West Iceland. The hydrographic material from this voyage has been published by MARTIN KNUDSEN (1905 Pl. XIX).

The occurrence of the *Ceratium* species is indicated on the chart fig. 2. We see from this:

1. That the occurrence of *Ceratium lineatum* to the south of Reykjanes is restricted to a narrow stripe, as the species does not occur on the stations here of the "Godthaab".

2. That *Ceratium lineatum* occurs from about 27° W. L. Hence it extends to the most westerly station next to the coast of East Greenland. This station is however scarcely in the East Greenland Polar Current.

From the last station, where *C. lineatum* did not occur, to the first where it did, the temperature fell from 11·7° to 10·8°. According to KNUDSEN the salinities were high, but the measurements scarcely to be depended upon.

3. *Ceratium tripos*, which decreases westwards, occurs however constantly in considerable number and does not grow rare until about 100 miles from the coast of Greenland. Inside it the coast-diatoms occur (especially *Chaetoceras debile*). It is thus not found as far westwards as *C. lineatum*.

Similar series of plankton-collections from the Denmark Strait have been published for the years 1898 and 1899 (OSTENFELD 1899, 1900) and for 1900 I have examined but not published them. In all the

years the same is the case: *Ceratium lineatum* occurs west of 25°—27° W. L., but not or rarely to the east of it, — and during all the years except 1898, it has been found as far as to the coast of East Greenland. With the same exception *Ceratium tripos* occurs far into the Denmark Strait where its distribution is limited by the diatom plankton, (see more concerning this below).

From this we may be justified in supposing, that this condition is normal. It must of course be connected with the hydrographic conditions in the Denmark Strait, and even if the measurements published (KNUDSEN 1899, 1900, 1905) do not always show a fall in temperature and salinity contemporaneous with the change in the plankton, these changes will however be found farther into the Denmark Strait. As stated by KNUDSEN ("Ingolf" 1898) this Strait has its own water-masses and its own rotation. Consequently it has also its own plankton. This and the coastal plankton of West Iceland are independent of each other, which in the present case is shown by the absence of *Ceratium longipes* in the Denmark Strait.

From the relation between *Ceratium lineatum* and *C. tripos*, we get the impression, that *C. lineatum* is or may be a wintering or cold form of *C. tripos*. Since, besides the fact that *C. tripos* constantly produces specimens of *C. lineatum* — as stated, the latter is also found on the south coast, though not in great number — it (*C. tripos*) seems under changed conditions of life to be able, so to speak, to transform itself totally to *C. lineatum* in such a manner, that nothing remains of its original form.

It lies near to ask whether a similar relation is not present between *Ceratium arcticum* and *C. longipes*. As the conditions were in August 1904 no signs of this were noted. They occurred together north of Iceland, *C. longipes* extended southwards to Vestmannaeyar and to the east of Iceland far into the mixture-region between the Færoes and Iceland (se chart fig. 2). Whence do all these southern specimens come? They cannot have come from *C. arcticum* because in that case they must have spread against the stream. The reverse should rather be the case, namely that *C. longipes* changed into *C. arcticum*, but this is not probable either, as *C. longipes* constantly occurs in great number together with *C. arcticum*, and as the last-mentioned even seems to be brought to the coast of Iceland by a current from the north.

C. longipes has not been found practically in the Denmark Strait. It is on the whole a species with a peculiar distribution. According to OSTENFELD's list of plankton from Iceland and Greenland routes in 1897—1899 it does not occur on the Greenland routes (on 58°—60° n. lat.) west of 10° W. L. except on the actual coast of Greenland. Between Scotland — the Faeroes — Iceland and at South Iceland it is common. In other words it seems to escape the warm Atlantic oceanic water. According to GRAN (1902) it is common in the Norwegian Sea.

Ceratium furca occurred commonly at the end of August 1904 from Snæfellsnes and southwards, not at all north of Snæfellsnes. Out in the Denmark Strait it has been found to some distance west of the eastern limit of *Ceratium lineatum*.

Ceratium fusus was on the other hand common along the western north coast, the west coast and the south coast and also in the whole Denmark Strait. It is a eurythermic species.

Ceratium intermedium has the same distribution at Iceland as *C. furca*, but extends in the Denmark Strait as far out as *C. tripos*.

With regard to the distribution of the Ceratium species east and south-east of Iceland I may refer to the chart (fig. 2), the data on which are based upon the "Bulletin des Résultats acquis", Août 1904. It is seen, that the limits given here are in agreement with those on the western side of Iceland. *C. tripos*, *C. furca* and *C. intermedium* are Atlantic species, which certainly occur in the region of mixed water, but not in the cold Arctic water. The conditions as regards *C. longipes* (and perhaps of *C. lineatum*, the northern limit of which I do not know) are the reverse: a northern species, which occurs in the mixed-water region, but not in the warm Atlantic water on station Da 7. *C. arcticum* is the most exclusive, it only lives in the cold water and does not even enter the mixed-water region.

C. The north coast of Iceland.

The post-steamers in 1904 and 1905 collected plankton on the following stations, taken from west to east: Cape North, Skagatá (the S. S. "Skálholt"), Gogurtá, Rödehuk and Lánganes (the S. S. "Hólar"). As on the west coast we may here take every station separately and investigate the changes through which the plankton has passed during the course of the year. Next we will endeavour to get a general view of them all, and to this we may add the observations and collections made from the "Thor".

Cape North. The collections have been made on the following days: in 1904 on the 20th of April, the 5th, 22th and 30th of May, the 16th of June, the 7th and 29th of July, the 13th of August, the 1st and 14th of September, the 5th of October, the 1st of November and in 1905 on the 20th of April, the 5th, 20th and 30th of May, the 18th of June, the 6th and 29th of July, the 13th and 31st of August, the 15th of September, the 5th and 27th of October.

The ordinary Thalassiosira plankton is predominant until June in both years. In early spring the two species *Th. gravida* and *Nordenskiöldii* are accompanied especially by *Biddulphia aurita* later by *Coscinosira polychorda, Chaetoceras debile* and *Diadema, Peridinium conicoides.* About the middle of July or towards the end the Dinoflagellates begin appearing, in 1905 they are however not common before far into August. Between the Thalassiosira and the Dinoflagellate plankton is found a poor period, in which the plankton essentially consists of diatoms *(Chaetoceras decipiens, debile, Rhizosolenia alata or semispina).* (Second diatom maximum, feeble.) In the Dinoflagellate plankton *Ceratium lineatum* and *longipes* are the most important, occurring most constantly and most commonly, next *Ceratium fusus*; but only a few specimens have been found of *C. arcticum, intermedium, furca* and *tripos.* Of small Dinoflagellates *Dinophysis norvegica, Peridinium ovatum, depressum, pallidum* and *pellucidum* occur somewhat constantly. To the Dinoflagellate plankton also belong *Chaetoceras decipiens* and several Tintinnids: *Amphorella subulata, Cyttarocylis gigantea* and *denticulata, Ptychocylis urnula,* less constantly *Tintinnus acuminatus* and *Tintinnopsis karajacensis var. acuta.* — In September and October in both years rather few *Thalassiothrix longissima* occur in several consecutive samples; this is a slight indication of a third diatom maximum, in 1905 are further found *Rhizosolenia styliformis* and *Shrubsolei,* and *Dictyocha speculum* especially in 1904.

Skagatà. The collections have been made on the following days: in 1904 on the 26th of April, the 1st, 23rd, 27th of May, the 19th of June, the 2nd and 9th of July, the 4th and 11th of September, the 10th and 20th of October — in 1905 on the 25th of April, the 22nd and 28th of May, the 21st of June, the 2nd of July, the 2nd and 9th of August, the 3rd and 11th of September, the 12th and 19th of October.

The Thalassiosira plankton persists in 1904 to the end of July, in 1905 it is only found in the three first samples. It is relatively rich: *Biddulphia aurita* is as usual an early form. Other companions of the two *Thalassiosira* species are: *Chaetoceras debile, Diadema, furcellatum, Coscinosira polychorda, Thalassiothrix nitzschioides, Peridinium conicoides. Fragilaria oceanica* and *Lauderia glacialis* only occurred in 1904, and *Chaetoceras sociale* and *teres, Nitzschia seriata* and *Rhizosolenia semispina* only in 1905.

The Dinoflagellate plankton does not appear before the beginning of August, in 1904 small Dinoflagellates (*Dinophysis rotundata* and *norvegica, Peridinium ovatum* and *pellucidum,* with *Ptycocylis obtusa* and *Cyttarocylis denticulata*) were however found already in July, but the *Ceratii* occur for the first time on the 2nd of August. These are: *C. longipes, C. lineatum* and *C. fusus.* In 1905 they appear much more sparsely than in 1904, especially *C. lineatum. C. arcticum* is found in few specimens in several samples in both years, the same is the case with *C. intermedium* in 1904. The small Dinoflagellates and Tintinnids mentioned are common, and together with these we also find *Peridinium depressum* and *pallidium, Cyttarocylis gigantea. Calanus finmarchicus* and *Oithona sp.* have been found rather regularly in both years towards the end of the summer, *Microsetella atlantica* and *Temora longicornis* also in 1904.

In August 1904 we find a second diatom maximum consisting of *Chaetoceras decipiens*. It is lacking in 1905 but in September—October of both years traces were found of a third diatom maximum: *Thalassiothrix longissima, Chaetoceras debile* and *decipiens, Coscinodiscus, Dictyocha speculum* are all found, but only in few specimens.

Gogurtá. The collections have been made on the following days: in 1904 on the 29th of April, the 26th and 29th of May, the 19th and 25th of June, the 24th of July, the 15th and 21st of August, the 13th and 18th of September, the 12th and 20th of October, and in 1905 on the 26th of May, the 25th of June, the 18th and 24th of July, the 15th and 21st of August, the 12th and 15th of September, the 13th and 21st of October.

The conditions are here somewhat different in the two years. In 1904 we find a rich Thalassiosira plankton which lasts to the end of June (between the 19th and the 25th), and in which, besides the main forms, the following are common: *Chaetoceras furcellatum, debile, diadema, convolutum* and *criophilum, Rhizosolenia semispina*. The presence of the three latter is a sign of an oceanic influence (comp. Paulsen 1904, the two Chaetoceras species are there given together under the name of *C. peruvianum*). The following species less commonly or constantly occurring are still worth mentioning: *Coscinosira polychorda, Fragilaria oceanica, Thalassiothrix nitzschioides, Chaetoceras laciniosum* and *Schüttii aff., Peridinium conicoides, ovatum, pallidum, roseum, Goniodoma Ostenfeldii, Codonella ventricosa*.

The sample from the 25th of June contains diatom plankton: *Chaetoceras laciniosum, diadema, constrictum, Leptocylindrus danicus* are the most important forms.

The sample from the 24th of July contains besides Dinoflagellates many *Chaetoceras decipiens*. The plankton of these two samples represents the second diatom maximum.

The Dinoflagellate plankton is almost quite without diatoms, *Chaetoceras decipiens* is however found in several samples. The most important *Ceratium* species are: *C. longipes* and *fusus*. In contrast to what in the case on the former stations *C. lineatum* does not appear living or in great quantities until in the samples of October. On the other hand several *C. arcticum* occur in July and August. *Peridinium depressum* and *ovatum, Dinophysis rotundata* and *norvegica, Cyttarocylis gigantea* and *denticulata, Amphorella subulata, Codonella ventricosa, Acartia* and *Oithona, Calanus finmarchicus, Pseudocalanus elongatus, Temora longicornis* and still more belong to this plankton.

A feeble but distinct third diatom maximum is found in October: *Corethron criophilum, Chaetoceras decipiens, gracile* etc., *Rhizosolenia styliformis, Thalassiothrix longissima, Dictyocha speculum*.

In 1905 we have no Thalassiosira plankton: only in the first sample we find some few dead specimens of *Th. gravida* and *Nordenskiöldii*. But two samples are rich in diatoms: that from the 18th of July with *Chaetoceros constrictum, simile, Wighami, laciniosum, gracile, Coscinodiscus subtilis* — and that from the 15th of August, where a maximum of *Chaetoceras simplex* occurs accompanied by *Skeletonema costatum*.

The sample between these two (the 24th of July) contains several *Chaetoceras decipiens* but few other diatoms (*Ch. gracile, debile*); the plankton of these three samples makes the "second diatom maximum".

For the rest the Dinoflagellates are most predominant in the samples from 1905: from May to August small species: *Peridinium ovatum, pellucidum, pallidum, brevis, depressum, Heterocapsa triquetra, Goniodoma Ostenfeldii*, — together with which we find *Cyttarocylis denticulata, Ptychocylis obtusa, Tintinnopsis karajacensis var. acuta, Acartia, Calanus finmarchicus. Ceratium longipes* does not occur in any way commonly before the end of August, *C. fusus* is constantly rare, *C. lineatum* does not appear before October. On the whole the *Ceratii* are slightly represented in 1905. The small Dinoflagellates seem to diminish in late summer, and likewise the Tintinnids; among the latter *Tintinnopsis karajacensis var. acuta* is replaced by *Cyttarocylis*.

Quite few specimens of *Coscinodiscus sp., Chaetoceras convolutum, debile* a. o., *Rhizosolenia styliformis* and *delicatula*, all occurring in October, give a very slight indication of a third diatom maximum.

Rödehuk. The collections have been made on the following days: in 1904 on the 23th and 30th of April, the 25th and 30th of May, the 19th and 26th of June, the 23th and 25th of July, the 15th and 22th of August, the 12th and 19th of September, the 12th and 21st of October, and in 1905 on the 26th of May, the 19th and 26th of June, the 18th and 25th of July, the 14th and 22th of August, the 12th and 19th of September, the 13th of October.

The first diatom maximum, the Thalassiosira plankton, is almost not found as such. At Rödehuk all the samples from April and May are very poor in plankton. Only in one sample (the 26th of May) from 1905 some few living *Thalassiosira* of both species occur; in this sample was also found a single chain of *Asterionella* and a few specimens of several small Dinoflagellates.

In June 1904 we have rather a rich diatom plankton corresponding to the end of the "first maximum"; it consist of: *Chaetoceras diadema, furcellatum, laciniosum, convolutum, Schuettii aff., Wighami, debile, criophilum, constrictum, Rhizosolenia semispina,* and together with these we find: *Goniodoma Ostenfeldii, Cyttarocylis denticulata, Tintinnopsis karajacensis var. acuta.*

In the month of July in both years the appearance of the plankton is quite otherwise; now we almost find no more diatoms, but the small Dinoflagellates are predominant: *Peridinium ovatum, pellucidum, pallidum, roseum, Steinii, depressum, islandicum, Dinophysis rotundata, Diplopsalis lenticula.* Together with these occur: *Ceratium arcticum* and *C. longipes,* — the latter especially has however not yet attained its maximum — and *Acartia, Calanus finmarchicus, Oithona, Pseudocalanus elongatus.* — In August and September the quantity of *C. longipes* increases, and still in October it occurs, especially in 1904 together with *C. fusus. C. arcticum* has not been found in any sample after October, and *C. lineatum* has in a living state only been found in some few specimens in the sample from the 12th of September 1904, whilst several dead specimens have been found in the sample from the 21st of October 1904. — *Peridinium ovatum, depressum* and partly *P. pallidum* are the only ones of the small Dinoflagellates, which accompany the *Ceratii* in the last samples, and *Codonella ventricosa, Cyttarocylis gigantea* and *denticulata* and the Copepods also occur rather constantly until late in the year.

A feeble "second diatom maximum" is found in July 1904, consisting of *Chaetoceras decipiens* and *Rhizosolenia styliformis,* and in October a third occurs, which is likewise feeble and consist of *Corethron criophilum, Coscinodiscus radiatus* and *Rhizosolenia styliformis.* In 1905 these are not found, the whole is reduced to a slight flowering in August—September of *Chaetoceras decipiens* accompanied by a few cells of *Rhizosolenia styliformis* etc.

Lánganes. The collections have been made on the following days: in 1904 on the 22th of April, the 1st, the 24th and 30th of May, the 18th and 27th of June, the 17th and 26th of July, the 14th and 23th of August, the 11th and 20th of September, the 11th and 23th of October, and in 1905 on the 29th of May, the 18th and 27th of June, the 17th and 26th of July, the 14th and 23th of August, the 12th and 20th of September, the 12th and 22th of October.

As on the two former stations a difference is present between the two years. In 1904 we have a rather rich Thalassiosira plankton, which keeps living til the end of June, and in which, besides the main forms we find: *Chaetoceras convolutum* and *criophilum, Rhizosolenia semispina, Chaetoceras diadema, laciniosum, debile, Bacterosira fragilis.* They all occur in one or several samples from the 24th of May (incl.); before that time the plankton is very scarce, containing besides some *Thalassiosira* a few *Biddulphia aurita, Coscinosira polychorda* etc.

In 1905 the spring and summer plankton is on the other hand extremely poor, the first two samples contain almost nothing, that from the 27th of June has several species in few specimens (*Chaetoceras convolutum, simplex, Nitzschia seriata, Rhizosolenia alata* etc.), and in this the small Dinoflagellates begin appearing: *Heterocapsa triquetra, Peridinium ovatum, faeroënse, pallidum, pellucidum, roseum, Diplopsalis lenticula,* — and further *Cyttarocylis denticulata* and *gigantea.*

From the middle of July the plankton is about the same in the two years: at that period *Ceratium arcticum* and *C. longipes* begin occurring, whilst *C. fusus* does not appear before August and is also constantly more rare. About the end of August *C. arcticum* disappears. *C. lineatum* only occurs living in September in small numbers, but in both years. In the sample from the 11th of October 1904 it is strange to meet with *C. furca*, though in small number, but living. — The most important of the organisms, which accompany *Ceratium longipes*, are in both years the following: *Peridinium ovatum* and *depressum*, *Dinophysis rotundata*, *Cyttarocylis gigantea* and *denticulata*, *Oithona*, *Acartia*, *Pseudocalanus elongatus*.

In both years a "second diatom maximum" is found in August (—September); it consists of *Rhizosolenia styliformis* and *Chaetoceras decipiens*, and in 1904 a distinct but feeble third maximum occurs, consisting of *Corethron criophilum* and a few cells of some few others. This third maximum is lacking in 1905, several, single and dead cells of different diatoms were however found in the last sample (22nd of October).

If we endeavour from the preceding to illustrate in few words the changes in the plankton on the north coast of Iceland in 1904 and 1905, we may do so as follows:

1. As on the west coast the spring plankton is a Thalassiosira plankton, which is predominant until about the end of June. With regard to this plankton (the first diatom maximum) the following is remarkable:
   a. It only occurs regularly in both years on the two most westerly stations (Cape North and Skagatá), and it has here mainly the same composition as on the west coast; *Biddulphia aurita*, *Chaetoceras debile* and *Diadema* are namely the most important companions of the *Thalassiosira* species.
   b. At Gogurtá and Lánganes the Thalassiosira plankton only occurs in 1904, not in 1905; besides the ordinary species it contained in 1904: *Chaetoceras convolutum* and *criophilum*, *Rhizosolenia semispina*, oceanic species, the original place of which is probably to the north (see PAULSEN 1904). At Rödehuk the Thalassiosira species are lacking in both years.
   c. A more distinct or a more feeble maximum of the diatoms, which accompany *Thalassiosira (Chaetoceras debile, diadema, convolutum, criophilum)* may however be noted at the end of June, except at Gogurtá in 1905. It is specially distinct at Rödehuk in 1904.
2. After the Thalassiosira plankton or the plankton by which it is replaced, we can note a feeble "second diatom maximum" in July or more rarely in August. Mostly it appears before the Dinoflagellate plankton, or it is mingled with the part, first present, of the latter. Its main forms are: *Chaetoceras decipiens*, later mingled with *Rhizosolenia styliformis*, but also other species occur, about which reference may be made to the preceding and to my 1904 paper.
3. At the end of July or the beginning of August the Dinoflagellate plankton appears; only at Gogurtà in 1905 it already begins in the month of May. The species first occurring are as a rule *Peridinium ovatum* and (except at Cape North) *Dinophysis rotundata*. We find commonly on all the stations of the north coast *Ceratium longipes*, which always occurs still in the last samples from October. It is accompanied by lesser quantities of *C. fusus*.

   The differences between the stations are:
   a. *Ceratium lineatum* is predominant from July—August on the two western stations, Cape North and Skagatá; on the three eastern stations it only occurs in small numbers and in the beginning of October.
   b. *Ceratium arcticum* is almost not found at Cape North, is rare at Skagatá, but at Gogurtá, Rödehuk and Lánganes it is an essential part of the plankton in July and August, but it is seldom found in June and September. We thus see, that it disappears long before *C. longipes*.
4. A third diatom maximum can sometimes be noted in October. The main form on the three eastern stations is *Corethron criophilum*. It has however not been found in 1905, but in 1903 it was present

in great numbers (PAULSEN 1904). On the two western stations *Thalassiothrix longissima* is the main form, which has been found in both years.

5. As a main result of the preceding it may be noted, that the conditions at the two western stations are essentially different from those at the three eastern, Gogurtá, Rödehuk and Lánganes. The dissimilarity appears in the following way:
   a. The Thalassiosira plankton occurs neither with the strength nor the regularity on the eastern as on the western stations, and on the eastern stations oceanic forms which are lacking on the western, are present (see PAULSEN 1904).
   b. The composition of the Dinoflagellate plankton is different. *Ceratium lineatum* is mainly bound to the western stations, *C. arcticum* to the eastern. *C. longipes* occurs on both.
   c. The "third diatom maximum" in October consists on the western stations of *Thalassiothrix longissima* on the eastern of *Corethron criophilum*.

On the whole the character of the eastern stations is colder and more oceanic than that of the western. In some regards the plankton of the latter has a likeness to that of West Iceland. We many here point out the occurrence of the Thalassiosira plankton, *Ceratium lineatum* and *Thalassiothrix longissima*, the last one being a main form of the oceanic plankton of the Denmark Strait.

The plankton of the eastern stations is apparently without any connection with that of the western stations; it is on the other hand certainly under the influence of the south-going Arctic Polar Current and its cold-water plankton.

We cannot give any reliable information about the cause of the dissimilarity between the plankton in 1904 and 1905. In both years water-samples were taken and observations of temperature made at the same time as the plankton-samples were gathered from the post-steamers. For various reasons however we cannot rely upon the hydrographic results obtained.

We may however note here, that on the western stations and at Lánganes and Rödehuk the salinity was as a rule greater in 1904 than in 1905, and the same is the case at Gogurtá during the first half of the summer. It is in agreement with this, that the East Greenland Polar ice was in 1904 not, or only in small quantity, in the immediate neighbourhood of the coast of Iceland, whilst in 1905 it was found: in April and May north of Iceland near Mevenklint, in June and July as a tongue near the land east of Cape North. In August 1905 it was absent again.[1]

Probably there is a connection between the presence of the ice and the changes in the plankton in 1905. But it is strange, that the difference between 1904 and 1905 appears almost entirely on the eastern stations, where the ice did not occur. With our present knowledge it is difficult to explain the most important change, the absence of the Thalassiosira plankton in 1905, by the presence of the ice, because, as is known, the ice just brings such plankton (see e. g. PAULSEN 1904). It seems easier to connect the ice of 1905 with the greater poorness (in individuals) of the Dinoflagellate plankton in 1905, as it is possible, that the reduced salinity and the on the whole changed conditions of life may have influenced the more sensitive Dinoflagellates.

The absence of the third diatom maximum *(Corethron)* in 1905 is probably also in connection with the ice. If my supposition is right, that *Corethron* is an oceanic species, which comes to Iceland from the north, the reason of its absence in 1905 was probably conditions of stream and ice far up in the north.

The following observations, made from the "Thor" in 1904, supplement the above record of the plankton at North Iceland in that year. In 1905 the "Thor" was not at the north coast when I was onboard.

At the end of April the Thalassiosira plankton was found at Cape North and at Lánganes; the first place was richest in individuals the last in species, *Chaetoceras criophilum* has only been found here.

[1] Nautical-meteorological annual. Copenhagen 1904, 1905.

A month later, in the end of May, the same plankton was present at Tiurnes, off Siglu Fjord, off Huna Bay and at Cape North. Only on the last named station *Chaetoceras criophilum* was lacking. For the rest they are all rich in diatoms. As an example is given here the sample from station 130, on 66° 17′ N. Lat. and 21° 14′ W. L. off Huna Bay on the 2nd of June 1904:

Phaeocystis Pouchetii cc, *Chaetoceras atlanticum* rr, *constrictum* rr, *convolutum* r, *criophilum* +, *debile* +, *decipiens* r, *diadema* +, *furcellatum* c, *teres* r, *Coscinodiscus* +, *Coscinosira polychorda* +, *Nitzschia seriata* r, *Rhizosolenia alata* +, *semispina* r, *Thalassiosira gravida* c, *Nordenskiöldii* c, *Thalassiothrix Frauenfeldii* +, *Peridinium ovatum* +, *Cyttarocylis denticulata* +, *Ptycocylis obtusa* +, *Nauplius* +.

The next time the "Thor" came to the north coast was in the end of the month of July, and this time also it came from the east. It sailed westwards from Lánganes to Skialfandi Bay and thence northwards, past Grimsey to 67° 19′ N., 17° 55′ W., (station 214), whence it took the direction south-eastwards in about a straight line to station 216, which lies about 60 miles east of Lánganes at 66° 15′ N. and 12° 13′ W.

On the whole first part of this voyage from north of Lánganes to Skialfandi Bay, Grimsey, station 214 and to ca. 40 miles south-east of the latter *Ceratium arcticum* (see chart fig. 2) was the predominant form in the plankton. Together with it the following occurred almost regularly: *Dinophysis rotundata, Peridinium ovatum, pallidum, depressum, Ceratium longipes* and *fusus*. Diatoms and Tintinnids are almost totally lacking, but *Calanus finmarchicus, Oithona* and *Nauplii* are common. On station 214, which is outside the coastal water, a diminution in the quantity of Dinoflagellates is seen and a maximum of *Phaeocystis Pouchetii*.

During the voyage from station 214 south-eastwards *Ceratium arcticum* gradually decreases, and about at the same longitude as Lánganes it almost completely disappears. The Dinoflagellates, which accompany it, continue however except *Peridinium breve*.

Somewhat to the east of the meridian 14° W. L. we suddenly find another plankton, the main forms of which are: *Chaetoceras convolutum* and *criophilum, Rhizosolenia semispina* and together with these: *Peridinium pallidum* and *pellucidum, Goniodoma Ostenfeldii, Dinophysis rotundata, Cyttarocylis denticulata* (see chart fig. 2). In addition not inconsiderable quantities of *Thalassiosira gravida* and *Nordenskiöldii* were found first in the surface-water at 13° 34′ W. L., thus near the western limit of the plankton last-mentioned and secondly on station 216 in a depth of 170—70 m. It seems to me to indicate, that this plankton at any rate partly is the remnant of the North Iceland coastal plankton, which has been swept out here by the Irminger Current.

This is not at all improbable because we know from Nielsen's paper, that the east-going Irminger Current along the north coast of Iceland was strong at that period, and in the work mentioned the station 216 (78) is mentioned on p. 21, and it is stated, that the surface-water like the bottom-water here belongs to the East Icelandic Polar Current, whilst at a depth of between 100 and 180 M. a water-layer is found, which must originate from North Iceland and must have been brought by the Irminger Current. The deep water-layer thus both hydrographically and planktologically indicates an origin from the north coast of Iceland.

With regard to the hydrographic observations on station 216 see Nielsen p. 5 (station 78).

Quite similar conditions as at station 216 were again found at about the same place in the middle of August (station 255, Nielsen's st. 101). According to Nielsen an intermittent water-layer is also found here, which originates from North Iceland and lies in a depth of about 100—200 M. The plankton at the surface consists of *Ceratium arcticum* and *C. longipes*, mingled with large quantities of *Rhizosolenia styliformis*. But few diatoms and Dinoflagellates are for the rest present. A haul with the closing net from 150—20 M. gave, besides the same species, several small *Peridinii* in many specimens: *Peridinium ovatum, pallidum, breve, islandicum, depressum*. Of these species *P. ovatum* and *breve* were found in the surface in few

specimens, the rest were lacking there. — Another haul in depths 350—230 M. gave the same species, though in fewer specimens, many *Microcalanus pusillus* and two cells of the sessile, coastal diatom *Isthmia nervosa*; the presence of the last mentioned here is of special importance, making it still more probable, that the small Dinoflagellates, in whose company it was, must originate from the coast.

In the month of August the "Thor" sailed again from the east along the north coast of Iceland. As far as Huna Bay the microplankton was the whole time the same, which we know from the collections of the post-steamers: *Ceratium arcticum* and *longipes* mainly accompanied by small Dinoflagellates, Copepods and Tintinnids especially *Cyttarocylis gigantea*. *Rhizosolenia styliformis* does not occur in great number in the surface-waters west of Lánganes, but off Siglu Fjord and in the Huna Bay it was found in deeper water-layers. Probably it here originates from the west from the Denmark Strait. In the deep water of Huna Bay, in a depth of more than 75 M., it is accompanied by (rather few) *Thalassiothrix longissima*, which, as known, is a main form of the plankton of the Denmark Strait. As already mentioned in more detail (p. 18, 24) the origin of the surface-plankton in the Huna Bay is also western, its main form namely being *Ceratium lineatum*. It occurs in huge quantities, accompanied by *C. longipes* and *C. fusus*; together with these we also find *Dinophysis rotundata*, whilst the rest of the small Dinoflagellates are absent.

Of the fjords on the north coast the Skialfandi Bay had in July and the Siglu Fjord in August the same plankton as the sea outside; they are both short and open fjords. The long Eya Fjord (Øfjord) is interesting; it was investigated at the end of August, and its plankton consisted of *Chaetoceras simplex* and *Skeletonema costatum* but for the rest with very inconsiderable mixture. *Chaetoceras simplex* has been described from the Caspian Sea and has later only been found on the Mediterranean coast of France (Ostenfeld 1901, Paulsen 1905, Pavillard 1905).

D. The east coast of Iceland.

In 1904 and 1905 the post-steamer "Holar" had but one station on the east coast viz: at Papey (the isle of Pap) on the southern part of the coast, to the south of the mouth of the Berufjord. The collections were made on the following days: in 1904 on April 19th, May 6th and 20th, June 4th, July 1st, Aug. 10th and 28th, Sept. 7th, Oct. 6th and 31st, and in 1905 on May 6th and 20th, June 3rd and 13th, July 2nd, 13th and 31st, Aug. 10th and 28th, Sept. 8th and 26th, Oct. 30th.

In 1904 and 1905 as in 1903 (see Paulsen 1904) the Thalassiosira plankton was unusually rich and lasted unusually long, disappearing only about the beginning of August. Among the species belonging here *Biddulphia aurita* is as usual a spring-form; *Chaetoceras debile*, *decipiens*, *Diadema*, *furcellatum*, *Coscinosira polychorda*, *Rhizosolenia semispina* appear all the time rather constantly, while the following appear only in few or single samples in great numbers: *Chaetoceras sociale, simile, Wighami, convolutum, criophilum, Fragilaria islandica*. Dinoflagellates and Tintinnids occur only singly and are often dead.

After the disappearance of the Thalassiosira plankton some of the diatoms still last for some time, especially *Chaetoceras decipiens* and *debile*, and in 1904 further *Coscinodiscus radiatus*, in 1905 *Chaetoceras constrictum* and *pseudocrinitum* and *Rhizosolenia styliformis*. (Second maximum of diatoms in September—October).

In both years — as in 1903 — the Dinoflagellates are very scarce at Papey especially the *Ceratii*. Only on September 26th some specimens of *C. lineatum* and *C. longipes* were found. Of small Dinoflagellates some appear at about the time of the disappearance of the Thalassiosira plankton. The most important are *Peridinium ovatum, pallidum, depressum, roseum, conicoides, Heterocapsa triquetra, Dinophysis rotundata*. Further, *Cyttarocylis denticulata* and *gigantea*. Of Copepods there are but few.

As indicated in my paper of 1904 (pag. 16) it is possible that the particular richness of individuals in the Thalassiosira plankton at Papey originates from the situation of the station near a plankton boundary, viz: the boundary of the plankton of Southern Iceland which lives in warmer water. It is possible that the mixing of the two kinds of water offers particularly good conditions for the thriving of the plankton organisms (OSTENFELD 1899).

According to observations made in 1904 on board the "Thor" the water at the northern part of the east coast had in May Thalassiosira plankton, but about the middle of July the same plankton that I have previously described from 1903, viz: a neritic Chaetoceras plankton, *C. convolutum, debile, Diadema, furcellatum, laciniosum, Coscinosira polychorda, Leptocylindrus danicus, Rhizosolenia semispina,* but very few *Thalassiosira. Peridinium pallidum* is the only frequent Dinoflagellate. In August *Ceratium arcticum* and *C. longipes* are prevalent.

The plankton of the eastern fjords. In April and May all fjords examined contain Thalassiosira plankton. These fjords are the following: Berufjord, Rødefjord, Eskefjord, Nordfjord, Seydisfjord. In the middle of July Seydisfjord and the adjacent Lodmundarfjord were examined. *Chaetoceras laciniosum, furcellatum, debile* and several other species are here prevalent, in other words, the plankton is here the same as outside the fjords. A similar plankton was found in Möfjord (Mjöfifjordur) on August 30th. Further *Fragilaria* sp. and *Leptocylindrus danicus* were here common.

On July 18th the water was blood-red in Seydisfjord, which according to the statement of people who live there, is rather often the case. The colour originated from a Protozoon (fig. 4), which is probably the same that LOHMANN (1908) describes and figures under the name of *Halteria rubra* LOHM. I think however that the species ought to be called by its old name *Mesodinium pulex* (CLAP. & LACHM., STEIN). When seen from the side the organism has almost the shape of a hat. It is about 0·04 mm long. The lower part (corresponding to the brim of the hat) is most often more or less flattened downwards and rarely subglobular as in the existing pictures of *Mesodinium pulex* (CLAPARIDE et LACHMANN[1], VAN REIS[2], GOURRET et ROESER[3], RÜTSCHLI[4], LOHMANN[5]). The front part of the animal (the "crown" of the hat) is almost semicircular and rather sharply delimited from the hind part, the diameter of which is about double as large. When seen from above the animal is circular. The cilia-ring is situated like the ribbon round the hat. The animal moves very quickly with the crown foremost, but it can also spin round the crown like a top, which it does before dying. At the time of death the animal bursts into a thousand pieces, and the same thing occurs if we try to preserve it.

Fig. 4. Sketch of *Mesodinium pulex* (?) from Seydisfjord.

From the time about the middle of August we have again some investigations of the fjords. On August 10th the condition of Seydisfjord was rather peculiar. In the inner part of the fjord a rather poor Dinoflagellate plankton was found, in which were individuals of *Ceratium arcticum* and *longipes*, while *Peridinium ovatum, pallidum* and *depressum* besides *Ptychocylis obtusa* and *Cyttarocylis denticulata* were the principal organisms. Of diatoms there were practically none. At the mouth of the fjord in its approximate middle the plankton was altogether different. To begin with a great many diatoms were found here: *Chaetoceras Wighami, gracile, simile, laciniosum, cinctum, Ingolfianum, Nitzschia Closterium,* and further besides the above mentioned Tintinnids the following Dinoflagellates: *Heterocapsa triquetra, Glenodinium bipes* (both in great numbers), *Peridinium pallidum* and *pellucidum, Gonyaulax triacantha* and several others. Of *Ceratii* only a few isolated specimens were found.

Thus, a different plankton was found in the inner part of the fjord from further out, and, what

[1] Mim. de l'inst. nat. Génévois. V—VI—VII tab. XIV.
[2] Tijdschr. d. nederl. dierk. Vereen. Suppl. D 1. Afl. 2. 1884 Tab. XVI.
[3] Archives zool. expér. 4. 1886. p. 491, tab. XXX.
[4] BRONNS Class. a. Ordn. d. Thierreichs I p. 1688, tab. 55.
[5] LOHMANN 1908 p. 303 tab. XVII fig. 37—39.

sounds strange, the plankton in the inner part is the same as outside the fjord (*C. arcticum*), while in the mouth it is different. The explanation is however most probably the following: The flow and ebb of the tide flows on the northern and the southern side of the fjord respectively[1]. It thus seems very probable that water carrying *Ceratium arcticum* reaches the inner part of the fjord, while the old fjord-plankton is being carried outwards along the southern side by the current.

On Aug. 10th Rødefjord had almost the same plankton as the outer part of Seydisfjord: *Heterocapsa, Gonyaulax triacantha* and several *Chaetoceras* among which must be noted *Ch. pseudocrinitum* and *Ingolfianum*, occurring in great numbers. Quite a similar plankton was found at the same time in Möfjord.

In the latter fjord a number of homogeneous hauls were made at different places nearer or further from the two whale stations, which are situated on the fjord, one near the head and one near the mouth. This I did to ascertain the effect of waste and rottenness on the plankton. It has been asserted of the whale stations that they hurt the life in the fjords. In 1903 I found (Paulsen 1904) that this probably was not the case.

As far as the microplankton in 1904 is concerned, its distribution was evidently quite independent of the whale stations. There were more neritic organisms at the head of the fjord than at the mouth (*Chaetoceras laciniosum, simile, Gonyaulax triacantha* and others), but more *Ceratium arcticum* at the mouth. On the whole the difference was slight. The quantity was not large, less than in Rödefjord but as large as in Seydisfjord.

Nor does the macroplankton show any sign of suffering from the proximity of the whale stations. In Möfjord the greater part of the macroplankton was formed by young Euphausidæ and Copepods, and just outside the largest (outermost) whale station there was a great deal of plankton, more than inside the fjord, although the water was full of greasy lumps, which were also brought up in the net. At the mouth of the fjord the young Euphausidæ were less numerous, on the other hand there were more Copepods, and here were many *Limacina helicina* and fewer *L. balea*.

On the whole the result arrived at in 1903 is confirmed. If the whale stations have any influence at all on the quantity of plankton — which perhaps they have not — this influence tends towards an increase of quantity. No trace is found of any decrease.

E. The distribution of the separate species in the neritic plankton.

Above I have tried to give a statement of the distribution and alternation of the neritic plankton-community in the course of the summer. I shall now mention the distribution of the plankton-species separately.

A great many species appear on all the coasts of Iceland, though often in different quantities or at different times. *Thalassiosira gravida* and *Nordenskiöldii, Chaetoceras decipiens, debile, Diadema* and *furcellatum, Phaeocystis Pouchetii, Peridinium ovatum, Ceratium longipes, Cyttarocylis denticulata* and *gigantea* are examples of some of the most common. Below all the species are mentioned which are rather common and of limited distribution at the coast of Iceland.

Only at the south coast we find: *Halosphaera viridis* (see pag. 5) *Ceratium tripos*, as mentioned above very uncommon at the west coast.

Only at the south and west coast we find: *Asterionella japonica, Cerataulina Bergonii, Chaetoceras atlanticum, contortum, curvisetum, teres, Rhizosolenia Shrubsolei, Ceratium furca, intermedium, Dinophysis acuminata.*

[1] Den islandske Lods.

Only at the west coast we find: *Rhizosolenia setigera.* Found from Reykjavik to Isafjord. It is thus probable that its centre of distribution is in Faxe Bay.

Only at the west and north coast we find: *Amphorella subulata.* On the west coast this too goes southwards as far as to Reykjavik and thus seems to originate from Faxebugt. It appears also along the north coast, to which it may have been carried by the Irminger Current.

Only at the north coast we find: *Chaetoceras gracile* Schütt, *Chaetoceras simplex* Ostf. (see pag. 26). The latter seem to have its centre of distribution in Öfjord. When found at the north coast it is in Öfjord or to the east of it. This seems to be true also of *Chaetoceras subtilis.*

Only at the north and east coast we find: *Chaetoceras criophilum, Wighami, Ingolfianum, Ceratium arcticum, Glenodinium bipes, Peridinium roseum, breve, islandicum, Gonyaulax triacantha.*

I know no species which is found only at the east coast.

On the other hand the following are found at all three coasts except the east coast: *Peridinium crassipes, conicum.*

The species here enumerated have thus more narrow limits for their existence than the species, which are found in all the waters washing the coasts of Iceland. For if the former could keep living on all shores they would also be found there, as the oceanic currents must carry them from one shore to another. The wandering of fry round Iceland was proved by Schmidt, and as regards *Calanus finmarchicus* this wandering with the current was proved by Paulsen (1905).

It is in correspondence with the hydrographical conditions that several exclusive species are found to be common for the south and west coast and others for the north and east coast. It is in short the flora of the warm and the cold water.

F. The oceanic plankton round Iceland and in the northern part of the Atlantic.

1. To the south of Iceland.

It is known from the papers of Ostenfeld 1898—1900, which treat of the North Atlantic plankton[1] in 1897—99, how the different plankton communities alternate in the course of the year. In winter and early spring we find a poor plankton of Coscinodiscus species with a few *Chaetoceras atlanticum* and *decipiens.* It is succeeded at about the beginning of May by a rich oceanic diatom plankton ("Oceanic spring-plankton", "Nitzschia-Chaeto-plankton"). The most important of the leading organisms of the latter are *Nitzschia seriata, Chaetoceras Schüttii* aff., *Ch. pelagicum.* Of other species which are frequently seen here, there are: *Rhizosolenia alata* and *semispina, Chaetoceras decipiens, convolutum, atlanticum, constrictum, densum* and several others. It is somewhat variable in composition, and, what is also remarked by Ostenfeld, is irregularly distributed, occurs in shoals (1898 p. 83).

This plankton may be distributed eastwards as far as about the meridian of the Færoes, to the east of which at any rate its character is changed and it contains more southern forms. Northwards it is distributed as far as to the South Icelandic coast plankton. Its western boundary seems according to existing information (Ostenfeld's tables, material from 1900 still unpublished, "Godthaab's" collections from 1904) in May to lie between 21° and 27° W. (between 58° and 61° N. lat.). That is to say, the western boundary for this plankton is to the east of and not far from the submarine ridge, which stretches from the peninsula of Reykjanes towards the south-west. At these places the water over the ridge is certainly more than 1000 m deep, but it is to be supposed that the ridge is still of consequence in this connection. For

[1] See also Ostenfeld & Paulsen, Paulsen 1904, Bulletin des résultats.

nearer Iceland the water flows in the direction of the ridge, coming from the south-west, and it is colder to the north than to the south of the ridge (KNUDSEN, Ingolf). Thus the ridge of Reykjanes may also here be supposed to form a boundary between the warm water of the Atlantic and the mixed water of the Irminger Séa. It would also be in accordance with this that the Atlantic plankton stopped here. The boundary seems however, in June, July and August, to draw westwards or towards the north-west. This is already mentioned by OSTENFELD, and it is also shown by later material. In no year is the western boundary found in June to be to the east of 35° W. In August this plankton is generally found in the western part of the Denmark Straits. In August 1898 and 1904 it was however also found at 8° W., south-west of the Færoes on the large Færoe Bank.

It is not worth considering how the alternation of the plankton communities comes to pass in a sea like this, especially as the conditions of current and rotation are insufficiently known. In June—July we find the oceanic spring plankton mixed with Dinoflagellates, which for some time have the upper hand, while the diatoms disappear.

Where then do they come from next year?

In this connection I may call attention to a matter which has hitherto hardly been noted. I may elucidate it by an example. In the middle of May 1904 the "Thor" passed from the Færoes towards the south-west, down to the large Færoe Bank, which is situated on both sides of the line of 61° latitude and stretches as far as from ca. 8° to ca. 9° 25′ W (see chart fig. 2). Its greatest extension (N. E.—S. W.) within the 200 m curve is about 45 miles. It slopes rather quickly on all sides, the 600 m curve, which runs round it except to the N. E., is at a distance of 10—15 miles from the 200 m curve. Suderø, the nearest land, is 50 miles distant.

To the east and the north of the bank there was a rich diatom plankton, in which *Chaetoceras decipiens* was the prevailing form, and besides the following were abundantly represented: *Chaetoceras boreale, atlanticum, densum, Schüttii* aff., *pelagicum, Rhizosolenia alata.*

The samples taken to the north of the bank were somewhat different from those from the east; in the latter for instance *Ch. Schüttii* and *pelagicum* were replaced by *Ch. constrictum.* But on the whole we find the same plankton, which may be characterized as a kind of "oceanic spring-plankton". On the eastern part of the Færoe Bank station 77 was taken (depth 112 m). It immediately became evident that the quantity of plankton was many times larger than at the stations round it. The composition of the plankton was, though to some extent the same, still clearly different from that of the surrounding stations. Below, the difference is stated between the station on the bank (77) and station 78, which is situated about 15 miles N. W. of the bank (61° 08′ N., 9° 27′ W. depth 645 m). The following were found in much larger quantity on the bank than outside it: *Chaetoceres boreale,* forming the greater part of the plankton, while as mentioned before *Ch. decipiens* is the principal form outside the bank, *Ch. densum, Ch. debile, Thalassiothrix longissima,* wanting outside the bank; *Rhizosolenia styliformis,* wanting outside. To these we may add several rare species, which were only found here, e. g. *Lauderia borealis, Peridinium*-species, Cirriped larvæ and spawn and fry of cod (cf. J. SCHMIDT 1909, chart I), also wanting outside the bank.

The following station 78 off the bank had: *Chaetoceras Schüttii* aff., *Chaetoceras pelagicum, Coccolithophora pelagica, Dictyocha fibula* all wanting on the bank; *Cyttarocylis denticulata* f. *elegans,* many more; and several rare species.

The principal difference is in the proportional quantities, the absolute — the glass was filled to the brim with the plankton of the bank — as well as the relative, especially between *Chaetoceras boreale* and *decipiens.*

By its enormous quantity and for instance by the presence of *Chaetoceras debile* the plankton on the bank impressed one as a neritic plankton. The hydrographical conditions do not contradict this opinion. The result of measurements made by the hydrographer Mr. J. N. NIELSEN are stated here.

Depth	St. 77 (on the bank)		St. 78 (off the bank)	
	Temp. C°	Salinity ‰	Temp. C°	Salinity ‰
640 M.	...	...	7·72	35·26
500 -	...	...	86	26
400 -	...	...	88	26
330 -	...	...	93	26
200 -	...	...	8·06	26
110 -	7·62	35·26	...	...
100 -	...	...	8·16	28
75 -	62	26	—	—
50 -	62	26	16	28
25 -	62	26	19	29
10 -	72	—	—	—
0 -	78	28	20	30

Station 77 was taken at 6 p. m., station 78 at 7 a. m. the next morning. The water was nevertheless colder on the bank and was besides constantly a little fresher[1].

I do not know how this can be explained. It must however be a sign that the water on the bank is somehow prevented from having free communication with the surrounding water. As far as I know this is a question which has hitherto not been treated scientifically by hydrographers: What happens when a body of water — as here the Gulf Stream — moves towards a submerged flat? How will the water over the flat be renewed? This body of water will, if ascending and deviating currents be formed, no doubt be renewed but slowly. This seems to be proved also by what HJORT (1902) has found (HJORT & PETERSEN 1905), that the spawn of cod is found in great quantities on the isolated banks off the coast of Norway, while nothing or only very little is found over the channels which separate the banks. SCHMIDT also found spawn and fry of cod on the bank of Rockall but not outside it (l. c.). The plankton will then be able to grow and propagate on a bank just as at a coast. The enormous volumes on the Færoe Bank indicate particularly good conditions for alimentation, and this makes us think of NATHANSOHN's theory of the importance of vertical currents for the alimentation of the plankton. If the bank causes vertical currents on the side towards the Gulf Stream, the conditions will here be in correspondence with NATHANSOHN's theory.

It is noteworthy that on the return of the "Thor" to the Færoe Bank in the beginning of September 1904, a great many diatoms were found mixed with the Dinoflagellates prevalent at this time. Of these *Nitzschia seriata, Chaetoceras boreale* and *atlanticum, Rhizosolenia alata, Thalassiothrix longissima* were the most frequent, but it is of importance for a comparison with the spring to notice, that *Chaetoceras decipiens* and *debile* and *Rhizosolenia styliformis* were also present. It is thus the same plankton as in May. It was not found to the north of the 200 m curve, but S. E. of the proper shoal, at two stations within the 600 m curve and to the north of the deep Færoe-Shetland Channel. Whether this plankton has held out here since May I cannot unfortunately decide.

The "Laura" found here a similar plankton in the beginning of June, while in the middle of the same month the "Godthaab" did not find any. (It may have been there, however e. g. on another part of the bank). In the beginning of October it was still found in these regions but is was then thinner ("Laura").

If it is correct that the water on such banks is but slowly renewed, they may perhaps just for this reason play a part as reservoirs for the plankton organisms. It is possible that such banks may

[1] The same has been observed by Dr. J. SCHMIDT on the Rockall Bank (1909 p. 221). Here too neritic plankton was found.

serve as a sort of fixed quarters for the plankton organisms, a place where they live through unfavourable times and from which they spread when better conditions set in.

At about midsummer the number of diatoms disappear in the Atlantic, and the Dinoflagellates now prevail for the rest of the summer decreasing in number more and more as the autumn advances.

In the true Atlantic water the most important plankton organisms are the following: *Ceratium tripos, furca, fusus, intermedium, Peridinium ovatum, pallidum, crassipes, Diplopsalis lenticula, Dinophysis acuta.*

This is what OSTENFELD (1900) calls Scotica-plankton (*C. tripos var. scotica* = *C. intermedium*) or "oceanic summer-plankton" (1899). It is set up as a contrast to Longipes plankton ("northern Dinoflagellate plankton"), to which OSTENFELD considers *Peridinium ovatum, depressum* and *pallidum* to belong.

These are however also found in the true Atlantic plankton. Roughly considered these three on the one hand and *Peridinium crassipes* (= *divergens*) and *Pyrophaeus horologicum* on the other exclude each other, the last-mentioned are southern, more stenotherm or stenohaline forms. The "Laura" on her journey in August 1904 took a more southern course on her way home than out, and in correspondence herewith the southern route had considerably more *P. crassipes* and less *P. ovatum* than the northern. *P. ovatum, depressum* and *pallidum* are however frequently found together with the principal forms *Ceratium tripos* and *intermedium* in the more northern places for their appearance.

The two Peridinium species also pass beyond this, being frequent also in the longipes plankton.

As to the distribution of the *Ceratium* species see pag. 16 and chart fig. 2. On the latter the northern and southern boundaries for the species are marked out.

2. West of Iceland.

Our knowledge of the plankton of the Denmark Straits and the Irminger Sea is but slight. These waters are little navigated by ships. To the station Angmagsalik in East Greenland there is but one ship a year, in August or September. Plankton from these voyages in the years 1898 and 1899 is described by OSTENFELD, and the unpublished lists from 1900 and 1904 have been at my disposal. — In 1903 and 1904 the "Thor" was in the middle of the Denmark Straits. Of the first time I have already written (1904).

The ships bound for West Greenland pass the southern part of the Irminger Sea to the east of the Cape Farewell. Of the plankton fished here OSTENFELD has given an account (1898, 1899, 1900).

The material is not large enough for us to form a clear notion of the alternation of the plankton communities in this sea. The line to Angmagsalik is the most important, and from here we have plankton material from four years, which has been scientifically arranged and described. Only in one of those years (1898) was plankton taken as far west as in the polar current of East Greenland, which is easily seen from the temperatures published by KNUDSEN. The cold water was filled with *Chaetoceras criophilum* (?) and *Thalassiosira gravida* (there has probably been ice). For the rest the whole of the Denmark Strait was filled with a rich diatom plankton in August—September 1898 (*Nitzschia delicatissima, Chaetoceras laciniosum, debile, Thalassiosira, Bacteriastrum delicatulum* etc.). In the other three years it was different: in all three only the western part (of the warm water) of the Denmark Straits had diatom plankton, sometimes like the above-mentioned, sometimes (in 1904) chiefly consisting of *Chaetoceras debile* and *Rhizosolenia styliformis.* It has already been shown (pag. 18) that *Ceratium lineatum* belongs to this diatom plankton. *C. fusus* generally joins it, while *C. furca, tripos* and *intermedium* as well as *C. fusus, Dinophysis acuta, Peridinium pallidum, oceanicum, Diplopsalis lenticula,* sometimes even *Peridinium crassipes* all together form the plankton of the eastern part of the Denmark Straits. It is thus a proper "Scotica-plankton", not different from the usual North Atlantic.

It is the plankton of early summer in the Irminger Sea and the Denmark Straits that CLEVE and later OSTENFELD has called "Trichoplankton". The principal forms of this were in June 1904, off the

western peninsula of Iceland, the following: *Thalassiothrix longissima, Rhizosolenia semispina* and *alata, Chaetoceras convolutum* and *boreale, Nitzschia seriata.* It had a similar composition in 1903 to the west of Reykjavik (PAULSEN 1904). (OSTENFELD mentions *Chaetoceras peruvianum,* but be has taken this species in an extended sense. In the real cold water it is certainly principally *Ch. criophilum.*)

Among OSTENFELD's samples taken to the east of the Cape of Farewell we find again "Trichoplankton" from May and sometimes till September. It is however rather variable. Sometimes *Rhizosolenia styliformis* is found as well, or Dinoflagellates are present, among which *Dinophysis acuta, Peridinium pallidum* and *ovatum* are the most frequent. Sometimes neritic and Atlantic organisms are mixed with those of the "Trichoplankton", as in August 1900. On account of the just-mentioned case OSTENFELD and PAULSEN set up in their work a rather risky hypothesis of plankton, which was said to have come with currents from a distance. There is no reason to believe any such thing. The routes never go close to the southern point of Greenland, and if we examine the hydrographical data published by KNUDSEN, we may sometimes find a salinity of 35 ‰ right to the meridian of the Cape of Farewell. The measurements all show that temperature and salinity slowly sink towards the west, and we have thus a transition-territory before us. From the north the cold and ice-carrying polar current of East Greenland passes along the coast. On its eastern side it brings warmer "basin-water" originating from the Irminger Current. From the south (or south-west) warm Atlantic water passes up into the Irminger Sea and the Denmark Straits on its west-side taking with it some of the "basinwater".

The plankton described by OSTENFELD and PAULSEN must have been formed by a mixing of these three kinds of water.

Of the plankton from the Denmark Straits as described above for August—September the eastern Dinoflagellate plankton must be the pure or almost unmixed plankton of the Atlantic water, while the western diatom plankton is that of the "basinwater". If it contains *Thalassiosira* and other particularly neritic diatoms, the plankton certainly originates from a rim of ice. It is also in correspondence with this that the temperatures and degrees of salinity observed are higher for the former than for the latter kind of plankton. Their greater or less distribution in the different years depends on the extension of the different bodies of water.

3. East and North of Iceland.

Knowledge of the plankton from the East Icelandic Polar Current is obtained from the works by GRAN (1899, 1900, 1902), from the "Bulletin" and from my paper of 1904.

We know that the plankton in spring is uniform but quantitatively very rich, formed by *Chaetoceras criophilum* and further *Rhizosolenia semispina, Thalassiothrix longissima, Chaetoceras convolutum* and *atlanticum,* sometimes also *Ceratium arcticum.* The last mentioned is prevalent in late summer; it is accompanied by *C. longipes,* which never seems to be wanting, *C. fusus, Peridinium ovatum, Dinophysis rotundata,* rarely and only in transition territories by *Ceratium tripos* and *intermedium,* and still more rarely or almost never by *C. lineatum.*

These are the two plankton communities which are found regularly outside the neritic plankton of the north and east coast — if any such plankton be present — and the organisms of which are often found mixed with the latter (see pag. 23, 25).

II. MACROPLANKTON.

In the following I shall give an account of the principal species which form the macroplankton at the coasts of Iceland and in the seas outside it. By the principal is here meant the economically most important, i. e. those which are of the greatest use as food for the food-fishes. Such are of direct economical importance, but just as important, though indirectly, are many other organisms, especially diatoms and Dinoflagellates, which serve as food for the larger plankton animals, of which more will be said later on.

After an account of the composition of the macroplankton in the different seas, some particularly important groups of animals will be separately treated with regard to the geographical distribution of the species, their places of appearance, depth etc.

The section on the macroplankton may be considered under the following divisions:

G. The south coast of Iceland.
H. The west coast of Iceland.
I. The north coast of Iceland.
K. The east coast of Iceland.
L. Pteropoda.
M. Euphausidae and Hyperinae.

The weak point in these investigations on macroplankton made from the "Thor", is a consequence of the instrument which is generally used, namely PETERSEN's young-fish trawl (described by SCHMIDT 1904), and which cannot be closed but is brought to the surface open, so that surface-organisms get mixed with the species from the deep water.

It would no doubt be a remunerative task to study the vertical distribution of the larger plankton species by means of large and strongly fishing closing nets specially suited for the purpose, e. g. the pelagic "ring-trawl" constructed by Dr. SCHMIDT.

The definitions of the species mentioned in the following are given by: for the copepods Professor G. O. SARS, for the medusæ Dr. D. DAMAS, for the Euphausidae and several common copepods by myself from specimens determined by SARS. The names of other Decapod Crustacea I have taken from Dr. H. J. HANSEN's work on the Ingolf's Decapoda.

G. The south coast of Iceland.

Surface plankton. Already in April we find *Calanus finmarchicus* in large quantities (PAULSEN 1906) under the coast. It is accompanied by *Temora longicornis* and *Pseudocalanus (gracilis?)*, further out by fry of *Euchaeta norvegica*, specially at night.

In the last half of May the same species were found prevailing. At this time *Calanus* filled the whole surface of the sea from Ingolf's Høfde to the Færoes, while *Euchaeta* is the economically most important form from the deeper water. This may also be seen from the stomachs of some fishes caught al Ingolf's Høfde. Some small herrings contained almost exclusively copepods, especially *Pseudocalanus* and *Calanus*, and of the specimens of *Gadus Esmarkii* which were examined, the majority contained remains of copepods, especially *Euchaeta* and *Calanus*. Some remains of Euphausidae were however also found. Of these none were fished from the "Thor" at this time near land. The nearest were caught ca. 60 miles towards the south-west. On the other hand, *Clione limacina* and spawn were found right

up to the coast. SCHMIDT has repeatedly emphasized (1904, 1909) how rich the South Icelandic waters are in spawn.

In the open sea between Iceland and the Færoes we find besides *Calanus finmarchicus* the following species, generally at no large depths: *Thysanoëssa longicaudata*, *Eucalanus elongatus*, *Sagitta*, *Tomopteris*, *Limacina retroversa*, *Parathemisto oblivia*, Appendicularia, further *Physophora*, *Diphyes* and various large Radiolaria, and *Euchaeta norvegica* and *Rhincalanus nasutus*, which properly belong to greater depths, are sometimes caught near the surface of the sea.

Below, the bathypelagic fauna will be treated as a whole. About the middle of July the "Thor" was at the south coast of Iceland, and investigations were made at a number of stations near land as well as far out at sea, the most southern station was ca. 120 miles from the coast. The principal species of the microplankton were at this time of the year Ceratii. To the south of Iceland the macroplankton was at this time very rich. In the surface itself *Calanus finmarchicus* is as usual predominant, still not everywhere. There are a number of stations in the south-western part of the territory examined in July, where Calanus was entirely wanting in the surface water, while at one station it was found in great quantities at a depth of ca. 40 m, and at another at a depth of more than 240 m (hauls with closing net). A sketch of this distribution is found in PAULSEN 1906, Pl. II. This is an example of the fact that plankton is not uniformly distributed, but in shoals. Of other organisms found in the surface water itself *Limacina retroversa* and *Aglantha digitale* are the most important, in a single place near the coast also *Temora longicornis*. The large plankton species were caught with PETERSEN's young-fish trawl at a depth varying between about 60—10 m (this does noth mean that they cannot go deeper, but only that we generally caught them at such depths). The principal species are the following: Of pteropods *Clione limacina* and *Limacina retroversa*, often in great numbers, also *Clio pyramidata*. Of the Crustacea the Euphausidae are the most important: *Thysanoëssa longicaudata*, *Nyctiphanes norvegicus*, more seldom *Boreophausia Raschi* and *B. inermis*. The first-mentioned is the most frequent. The reason that they were not found at all stations (see charts fig. 8 and 9 and below) was no doubt, that they were not sought persistently enough at different depths.

Next *Euchaeta norvegica* is of great importance, appearing as it does frequently, especially in the night it was often caught in the upper water-layers. At some stations the small copepod *Euchirella rostrata* was almost as frequent. The following are of less importance: *Hyperia galba*, *Parathemisto oblivia*, *Euthemisto compressa* and *bispinosa*, the small ostracod *Halocypria globosa*, which was caught in great numbers at one of the stations at a depth of ca. 40 m, the deep-sea species *Sergestes arcticus*, which was taken at night at a depth of ca. 60 m in considerable numbers, and the following which were caught near land: larvæ of *Mysis mixta*, *Anomalocera Patersonii*, larvæ of crabs.

Lastly, the annelid *Tomopteris* is of importance. This also originates from deeper water. On the other hand, the following medusæ belong to the surface: *Staurostoma arctica*, *Tiara pileata*, *Physophora*, *Beroë*, *Corymorpha nutans*, *Cyteandra areolata*, *Stomobrachium norvegicum*. *Aurelia* and *Cyanea*, which are so frequent at the north coast, are absent here.

If we take the two economically (as food for fish) most important species in this fauna, *Euchaeta norvegica* and *Thysanoëssa longicaudata* and compare their vertical occurrence we find, that on the whole they appear together. In the day both have been fished rather regularly from the "Thor" at a depth of ca. 40—60 m, while they were wanting in the upper water-layers, but in the night both come up to the surface of the sea or at least very near. Once at a night-station I even found, that while both were present in great numbers from the surface to a depth of ca. 20 m, neither was found at a depth of ca. 40 m.

On the whole it must be said that the macroplankton of the summer time is rich in the sea to the south of Iceland, and from the "Thor" we have also seen fishing whales in these waters. Thus, when we are informed by SCHMIDT (1904 p. 71), that the cod from the southern waters is never

found with "Kril" (Euphausidae) in its stomach, but that it feeds on animals from the bottom, the reason cannot be that there is no macroplankton — "Kril" as well as other kinds of good food — in the sea to the south of Iceland. On the contrary a pelagic organism in these waters would obtain a good livelihood. Nor is the rich fauna confined to far out at sea, it goes — mixed with some neritic copepods and others — right up to the coast.

Of the species named above some are really surface animals whilst others belong to intermediate water-layers. Of these *Euchaeta norvegica* may be taken as type.

GRAN (1902 p. 95) briefly describes a "Euchaeta-region" comprising the deep water layers in the North Atlantic Current. These water-layers in the Norwegian Sea are according to GRAN poor in species and individuals, at any rate in the summer. *Euchaeta norvegica* is the most important, characteristic form.

In the years 1904 and 1905 deep hauls with PETERSEN's young-fish trawl have been made in Atlantic water to the south and west of Iceland at altogether 12 stations, and these hauls have brought to light a rich deep-water plankton. The young-fish trawl, as is well known, is an apparatus which fishes very well and accordingly gives large catches, but when used for deep hauls it has, as said before, one defect, viz. that it comes to the surface open and thus fishes in all the upper water-strata as well. It is therefore very difficult to see whether an organism which is found in the upper water-layers, but which is also caught in numbers at great depths, is really found in the latter. The decision of this question is dependent on comparisons of the frequency of the organism concerned in hauls from different depths. Moreover too few hauls with the young-fish trawl have been made at most stations, and for hauls with the closing net there has generally been neither time nor opportunity — the "Thor"s cruises were chiefly made for fishery purposes — so that it will be understood that what I can give regarding the vertical distribution of the species is only fragmentary.

Euchaeta norvegica has often been mentioned above; it appears frequently at or near the surface of the sea, especially in the night, but it is then generally not full-grown individuals or fry.

There is no doubt that it belongs to intermediate depths; in deep hauls it is always fished in great numbers, and often with eggs fixed on it. When DAMAS gives the isotherm for 1°—2° C. as the upper boundary for the appearance of *Euchaeta norvegica*, this cannot at any rate apply to the territory which is treated here, as such low temperatures are not found here, or at any rate only at very great depths near the Iceland-Færoe ridge. DAMAS & KOEFOED say (p. 397) that Euchaeta seems to be an animal of the temperate waters, growing rare in the polar current, which makes it descend to greater depths. *Euchaeta* is the most frequent organism from the intermediate layers in the northern Atlantic, it is brought up in great numbers in all deep hauls, and we are thus justified in using GRAN's name Euchaeta region for the deep water-layers to which it belongs. According to the few observations I have made, the upper boundary for this region lies at a depth of ca. 300 m. At greater depths than 300 m we always find not only Euchaeta but a greater or smaller number of the other animal forms of the Euchaeta-region. Of these I will first mention the Euphausidæ *Nyctiphanes norvegicus* and *Thysanoëssa longicaudata*, of which we have already spoken. Like Euchaeta these are not surface-forms, but often appear in the upper water-strata just as they may go far down. The case is somewhat similar with *Clione limacina*, and the following Crustacea have also been caught near the surface at night: *Sergestes arcticus* KR., *Rhincalanus nasutus* GIESBR. *Eucalanus elongatus* DANA., *Heterorhabdus norvegicus* BOECH., *Euchirella rostrata* CLAUS.

Below, a list is given of the bathypelagic plankton animals which have been fished by the "Thor" in the deep sea of the Atlantic north of Lat. 60° N., so far as they have been determined. These animals never reach the surface-water, they belong to a deep sea region similar to that named by GRAN the Cyclocaris-region, which however is arctic.

For the copepods I use the names which Professor G. O. SARS has given me, while the names of

the decapods originate from Dr. H. J. HANSEN's "Ingolf" paper. The material originates from 12 stations in 1904 and 1905, at which deep hauls have been made from the "Thor". Of these stations one is situated over the ridge between the Færoes and Iceland and two in the Denmark Straits. At the former and one of the latter *Calanus hyperboreus* was found in the deep water, while for the rest this species has not been caught. The other stations are all in the Atlantic to the south of Iceland, some to the west of the Færoes. At all the stations there has been fished with the young-fish trawl with 600—1800 m of wire out, different at the different stations, consequently at a real depth of ca. 400—1000 m.

The species which have been caught at most stations are the following:

Decapoda: *Sergestes arcticus* KR., *Acanthephyra purpurea* MILNE-EDW., *Thysanopoda acutifrons* HOLT & TATT., *Boreomysis microps* G. O. S., *Nematobrachion boopis* CALM., *Gennadas elegans* S. J. SM.

Copepoda: *Rhincalanus nasutus* GIESBR., *Gaidius tenuispinus* G. O. S., *Arietellus setosus* GIESBR., *Gaëtanus Caudani* CANU., *Gaëtanus armiger* GIESBR., *Euchirella curticauda* GIESBR., *Lophothrix frontalis* GIESBR.

More rarely, at 1—3 stations, the following has been caught:

Decapods: *Acanthephyra gracilis* S. J. SM., *Acanthephyra Batei* FAX., *Pasiphaë tarda* KR., *Parapasiphaë sulcatifrons* S. J. SM., *Nematoscelis megalops* G. O. S., *Stylocheiron maximum* HANS., *Stylocheiron longicorne* G. O. S., *Gnathophausia zoëa* WILL-SUHM., *Eucopia unguiculata* WILL-SUHM., *Boreomysis tridens* G. O. S., *Boreomysis nobilis* G. O. S., *Boreomysis arctica* KR., *Longithorax fuscus* HANS., *Meterythrops picta* HOLT & TATT., *Paramblyops rostrata* HOLT & TATT., *Pseudomma roseum* G. O. S., *Pseudomma affine* G. O. S., *Hansenomysis Fyllae* HANS.

Copepoda: *Amallophora magna*, *Augaptilus squamatus* GIESBR., *Augaptilus laticeps* G. O. S., *Augaptilus longicaudatus*, *Chirundina angulata* G. O. S., *Chiridius armatus* BOECH, *Eucalanus elongatus* DANA, *Euchaeta mixta* G. O. S., *Euchirella rostrata* CLAUS., *Heterorhabdus papilliger*, *Gaëtanus Kruppi* GIESBR., *Gaëtanus latifrons* G. O. S., *Gaëtanus pileatus* FARR., *Lucicutia grandis* GIESBR., *Macrocalanus longicornis* G. O. S., *Metridia princeps* GIESBR., *Onchocalanus cristatus* W., *Onchocalanus falcatus* G. O. S., *Paraetideus armatus* (BOECK), *Pleuromamma robusta*, *Scottocalanus securifrons* (SCOTT), *Undeuchaeta pustulifera* G. O. S., *Undeuchaeta australis* (BRADY), *Xanthocalanus borealis* G. O. S.

To these we may further add the following, which have been taken to the south of Iceland in the closing net (600—240 m): *Boreophausia Raschii* (one specimen), *Parathemisto oblivia*, *Calanus finmarchicus* (many), *Conchoecia daphnoides* (some), *Conchoecia obtusa* (many), *Conchoecia sp.*, *Scolecithricella minor* (Brady), *Tomopteris*, *Spadella*.

Cyclocaris Guilelmi has been taken a single time to the west of the Færoes, and *Halipages fulvocinctus* (M. SARS) at a station over the Iceland-Færoe ridge (c. 170 m depth).

Other not more exactly determined animals belonging to the Euchaeta and deep sea-region are: Radiolaria, *Aglantha* and other Medusæ, (*Rhopalonema funerarium*), large Chaetognaths, huge Ostracods and various Scopelini.

A statement, which I have formerly given of the deep-sea life, I must here recall. In my paper of 1904 it is said, pag. 15, of the surface-plankton, "that nearly all organisms descend to a depth of at least 1000 m". This was to apply to *Chaetoceras decipiens* among others. In this statement I do not believe any longer, my reason being the following: Plankton-nets, which go down open, also fish while they are being let down. If this is only the case as the net touches the sea and is filled with surface-water, or if it also happens later on, I do not know, but that it does happen I have convinced myself by sending down the lead so early that the net closed while being lowered, — it ought then to be brought up empty, which it was not; it contained a distinct though but small quantity of phytoplankton.

H. The west coast of Iceland.

Already in the month of April *Calanus finmarchicus* lives in great numbers at the west coast, the same is the case in June and August, consequently in all probability all the summer through. In June we find in and near the surface besides *Calanus* some other small Crustacea: *Acartia longiremis, Centropages hamatus, Pseudocalanus elongatus, Paracalanus parvus, Temora longicornis, Philomedes Liljeborgii, Evadne Nordmanni, Dulichia spinosissima, Podon Leuckartii, Cyphonautes,* larvæ of crabs, of Euphausids, Annelid-larvæ, Cirriped larvæ, Oikopleura — also *Philomedes brenda* may sometimes appear here, according to G. W. Müller a meroplankton species. Also *Mysis mixta* occurs here.

The species mentioned here are on the whole neritic. In the north-western part of Iceland with its many fjords and large banks they find good conditions for life, and so they do in Faxa and Brede bay[1]. Young of cod about 10 cm long from Isafjord had their stomachs filled with copepods, and other young fishes had sought the same food.

Several other neritic plankton animals are found at the west coast of Iceland, especially Medusæ: *Hippocrene superciliaris, Staurostoma arctica, Phialidium* (?), *Sarsia* sp. etc., the Annelid *Autolytus,* — mixed with oceanic organisms, such as *Physophora* and *Aglantha.* We may further add the Euphausidæ, which are frequent in the Denmark Straits and towards the coast, but not found in the fjords.

The fauna of plankton animals in the Denmark Straits is in certain things like that of the Atlantic to the south of Iceland. The water too is of a similar kind, being at the surface at least Atlantic. To the west of the north-western peninsula of Iceland the deeper water-strata are however often of arctic origin. In the course of a day and a night the hydrographer on the "Thor" has observed, that the water at a depth of 600 m changed at the same station from a temperature of 0°·2 and a salinity of 34·72 ‰ to 5°·83 and 35·11 ‰ respectively.

The fauna in the Atlantic water-strata is, as said before, like the Atlantic fauna, but is of a somewhat colder character, which is seen for instance in the ordinary appearanee of *Boreophausia inermis.* Besides the latter the following Euphausidæ are present: *Thysanoëssa longicaudata* and *neglecta, Nyctiphanes norvegicus,* of which especially the first and last-mentioned are common. *Euchaeta norvegica* too is generally present and besides *Clione limacina, Limacina helicina, Tomopteris, Sagitta, Physophora, Aglantha, Hyperidæ, Appendicularia;* young of *Sebastes, Calanus finmarchicus,* etc. — At the stations where there was cold arctic water as substratum the plankton was mixed with great quantities of *Calanus hyperboreus* and *Limacina helicina,* and these are also found far up in the warmer Atlantic water-layers, so that in these layers were found e. g. *Limacina helicina* together with *L. retroversa,* though the former is of arctic, the latter of Atlantic origin.

The greater number of larger plankton organisms were found from a depth of 40 m and downwards.

I. The north coast of Iceland.

In June the principal organism of the macroplankton is *Boreophausia inermis* and further *B. Raschi.* The *Thysanoëssa* species are only found at some stations, and *Nyctiphanes* has not been found at all. On the whole the plankton is richer in the deep water than in the surface. Of organisms of the macroplankton, which appeared rather frequently, we may mention *Calanus hyperboreus* along the eastern part, *C. finmarchicus* along the western part (cf. Paulsen 1906), larvæ of crabs in zoëa-stage, various *Hyperidæ,* especially *Parathemisto oblivia; Beroë.*

[1] Samples of Macroplankton collected in May, June and July 1909 in Faxa Bay by Capt. G. Hansen have shown me that though there is no real darkness in the night at this time of the year, yet the plankton-organisms occur more frequently and in greater masses in the surface of the sea at night-time than during the day. The samples were taken alternately day and night. — Nevertheless sometimes great shoals of Calanus finmarchicus occur in the surface in the day-time.

Along the western part of the coast the macroplankton was richer than along the eastern part, besides *Calanus finmarchicus* we found *Limacina retroversa* and *helicina*, *Pseudocalanus elongatus*, *Acartia longiremis*, *Philomedes Liljeborgii*, *Appendicularia* and of Medusæ especially a small species, viz. *Amphicodon prolifer*, as well as *Hybocodon islandicus* (?), *Hippocrene superciliaris*, *Aglantha*, etc.

With regard to many of these species it is here the branch of the Irminger Current coming from the west, by which they are influenced. This may with certainty be concluded of the following: 1) *Limacina retroversa*, the eastern boundary of which at this time was at Long. 19° 22′ W. 2) *Calanus finmarchicus*, the first of which were found 45 miles west of the above longitude. 3) Fry which, when coming from the west, we only met at Cape North. (Schmidt 1904, Paulsen 1906). Later on all three were distributed along the whole of the north coast.

Young of *Cottus scorpius* (5 cm long), had remains of Copepods in their stomachs.

In the days from July 20th till 22nd the "Thor" was again at the north coast of Iceland. It passed from Lánganes to the bay of Skialfandi and from there northwards past Grimsö (see chart fig. 1). The plankton was now quite different from that in June. The surface was full of young of *Calanus finmarchicus*, a net with an opening of 1 m could take one liter (more than 400·000) in about 10 minutes. Euphausidæ we did not see this time, but there were many *Euthemisto* and *Parathemisto* at some stations. *Spirontocaris*-larvæ were found rather regularly, also fry in large quantities, especially of cod and *Drepanopsetta*. The Medusæ especially were very frequent: *Cyanea capillata* (more rarely *C. Lamarckii*), *Aurelia aurita*, *Amphicodon prolifer*, *Staurostoma arctica* and *Beroë cucumis*.

I have before mentioned (1906), that there were many herrings on the north coast at this time, and that *Calanus finmarchicus* and sand eels (*Ammodytes*) formed their principal food.

On the voyage northwards past Grimsö it could be observed how the macroplankton of the surface changed. The number of Medusæ and young-fish decreased towards the north; the latter at last disappeared altogether. *Clione limacina* appeared however frequently and in very large specimens too. *Calanus finmarchicus* is found in great numbers right up to the most northern station. According to Nielsen (1905, Sect. VI) the coastal water goes as surface-water 50 miles out reaching the outermost station but one, and just here we find the last *Cyanea* and young cod (cf. above pag. 25). Thus *Calanus finmarchicus* is here found outside the coastal water.

At two of these northern stations (210 and 214) hauls were made with the young-fish trawl at a depth of ca. 300—500 m. Of organisms which have lived here, in water of from less than 1° to ca. 2°, the most frequent are the following: *Euchaeta norvegica*, *Calanus hyperboreus*, *Boreophausia inermis*, *Conchoecia maxima*, *Sagitta*, *Parathemisto oblivia*, *Aglantha digitale*. At the more southern station (210) there were many *Thysanoëssa longicaudata*, at both stations a number of *Nyctiphanes norvegicus*. At the northern station (214) there is reason to notice the appearance in deep water of the following species: *Pasiphaë tarda*, *Boreomysis nobilis*, *Calanus helgolandicus*, *Metridia longa*, *Gaidius tenuispinus*, *Chiridius obtusifrons*, *Amallophora magna*, *Heterorhabdus norvegicus*, — according to Sars (1903) all except *Calanus* arctic species, of which however e. g. *Amallophora magna* appears right down in the tropical Atlantic[1].

Exactly the same fauna was found a few days later at station 216 far to the east of Lánganes at Long. c. 12° W. Here too *Nyctiphanes norvegicus* was found. Of this station it has been noted above (pag. 25) that there was a water layer originating from the Irminger Current along the north coast of Iceland. At this station a great many large cod were caught, which lived pelagically here. They were caught with hooks in intermediate depths. Their stomachs were full of Euphausidæ (Schmidt 1904, p. 70).

The same water-layer originating from the west was found at about the same place at the end of August (Station 255) (Nielsen 1905), and as stated above the microplankton also now showed signs of

[1] A detailed account of the copepods of intermediate and deep water-layers in the arctic ocean has been given by Damas & Koefoed (p. 393 f.).

having come from the north coast of Iceland. Unfortunately we have from this station no deep haul with the young-fish trawl. *Microcalanus pusillus* was caught in numbers in the closing net at 350—230 m. In the surface the young of *Calanus finmarchicus* lived in great quantities and at a depth of up to ca. 40 m, a great many young of *Thysanoëssa longicaudata*, further *Sagitta, Aglantha, Beroë, Limacina helicina*, and *retroversa*.

At the end of August the north coast of Iceland had a macroplankton similar to that in July, still somewhat richer in quantity and composition.

Calanus finmarchicus is still predominant by its enormous numbers and besides, the following were more or less common: *Thysanoëssa longicaudata* (young), *Limacina helicina* and *retroversa*, *Temora longicornis, Evadne Nordmanni, Podon* (*Leuckartii*?), Cirriped larvæ, Echinoderm larvæ, *Centropages hamatus, Pseudocalanus elongatus*, *Paracalanus parvus*, *Spirontocaris*-larvæ, *Parathemisto* and *Euthemisto*, especially *E. libellula*, *Acartia* sp., *Clione limacina*, *Hyperia galba* (caught with medusæ), *Philomedes Liljeborgii, Amphitopsis glacialis*. We must further add: large quantities of fry of cod, haddock, long-rough dab (*Drepanopsetta*) and other fishes, the stomachs of which were full of plankton Crustacea, especially *Calanus finmarchicus*, and lastly numerous medusæ, among which *Melicertidium octocostatum*, *Cyanea capillata, Margelis* sp., *Staurostoma arctica, Aurelia aurita, Aglantha digitale* are the most frequent.

This is a complex fauna consisting of three different elements:

1. Endogenetic, neritic species. To these the majority of the species certainly belong: *Evadne, Podon, Centropages, Acartia, Pseudocalanus, Paracalanus, Philomedes*, larvæ and certainly many medusæ.
2. Allogenetic and oceanic species coming from the north with the Polar Current: *Limacina helicina, Clione limacina, Euthemisto libellula*, probably also *Aglantha digitale*.
3. Allogenetic, coming from the west with the Irminger Current: *Calanus finmarchicus, Thysanoëssa longicaudata* (?), *Limacina retroversa*, young fishes and probably several medusæ. All of this group are also oceanic except the young fishes and the medusæ.

Of the plankton from the deep water at this time of the year we have only information through a haul with the closing net in the Huna Deep (190—75 m). Here we found *Calanus hyperboreus* besides several of the ordinary surface-organisms (*Pseudocalanus, Temora, Calanus finmarchicus*).

K. The east coast of Iceland.

In April 1904 we find that *Boreophausia inermis* is the economically most important of the organisms of the macroplankon. It has been fished in great numbers at several places, mostly in deeper water-layers, and it proved to serve as food for cod. *Thysanoëssa longicaudata* has also been taken a few times, and of other organisms there is reason to mention: *Calanus hyperboreus* and *finmarchicus, Pseudocalanus elongatus, Sagitta, Microsetella atlantica, Oncaea conifera, Autolytus sp., Beroë*, larvæ of crabs. On the whole the plankton is poor.

This is also the case at the end of May. Now *Boreophausia inermis* is also the most frequent and probably the only economically important form. Small larvæ of crabs are very common, and *Calanus* seems to appear more frequently than in April.

For the rest almost the same species occur. At the northern east coast some *Thysanoëssa neglecta* and *Hyperidæ (Euthemisto bispinosa)* were caught. — As Schmidt has informed us (1904 pag. 69) the cod feeds here in the eastern part of the land chiefly on "Kril" i. e. Euphausidæ.

In the last half of July when the "Thor" again came to the east coast of Iceland the macroplankton was richer. An enormous number of young *Calanus finmarchicus* lived especially along the northern part of the east coast, and *Pseudocalanus elongatus* too was very frequent. As far as *Calanus* is concerned it

must have come from the north coast (PAULSEN 1905), and in the same manner as there (see pag. 39) the first of the pelagic fry of the cod come after *Calanus*, young cod being found at this time along the whole of the north coast as far as south of Lánganes, but not along the east coast (SCHMIDT 1909, chart IX N. 3).

Of Euphausidæ hardly any were found at the east coast at this time, just as at the north coast they had gone farther out like *Calanus hyperboreus*, for the latter and *Boreophausia inermis* were caught at pelagic stations off the southern as well as the northern part of the east coast, at the former also *Thysanoëssa longicaudata*.

Besides quantities of various Decapod larvæ (of crabs, *Spirontocaris*, *Galatea*) we find in July at the east coast: *Sagitta*, *Limacina helicina*, *Hyperidæ*, *Acartia*, *Autolytus* and various medusæ, such as *Catablema eurystoma*, *Amphicodon prolifer*, *Beroë*, *Staurostoma arctica*, *Sarsia sp.*, *Cyanea capillata* and *Aurelia aurita*. Of young fish the young of the capelan (*Mallotus*) are especially frequent. As an object of curiosity we may mention: *Dulichia spinosissima* KR.

In August the macroplankton is in the main exactly as in July. In the surface *Calanus finmarchicus* is present in great numbers, at many places *Evadne Nordmanni*, *Pseudocalanus elongatus* (mostly young), and Decapods as well, and to these we may further add at small depths: young of Euphausidæ, which, as far as I have been able to determine, belonged to *Thysanoëssa longicaudata*. In the deep water farther out many *Nyctiphanes norvegicus*, *Boreophausia inermis* and *Thysanoëssa longicaudata* were fished. The young of the cod now went as far south as to Glettinganes in the middle of the east coast (SCHMIDT 1909, chart IX N. 4). The medusæ were as in July.

In the cold current washing the east coast of Iceland as well as the north coast we find some larger plankton organisms, which but rarely come near land as they belong to greater depths.

Among these the most important is *Calanus hyperboreus*, a real cold-water inhabitant, which sometimes goes right up to the surface of the sea, but which only appears constantly and in great numbers at a depth varying from below 100 m to more than 400 m[1]. Other oceanic cold water forms are: *Metridia longa*, *Euthemisto libellula*, *Oncaea conifera*. To these belong further: *Boreophausia inermis*, *Clione limacina*, *Limacina helicina*.

At great depths in cold water live: *Cyclocaris Guilelmi*, *Euchaeta barbata*, *Chiridius armatus*, *Conchoecia maxima*[2] etc. These last-mentioned are hardly of any importance for the useful fishes.

L. Pteropoda.

The northern species of Pteropoda have been treated by BOAS and lately by MEISENHEIMER. With regard to distribution the paper by the latter author — being the latest — is of the greatest importance. MEISENHEIMER has also charted the distribution of the species in an excellently clear way. But there is an objection which may be urged against his chart, viz. that the southern boundary of the arctic zone does not go south of Iceland as MEISENHEIMER has delineated it. On the contrary it touches land at the Horns and at the north-western part of the country.

It was originally my intention to treat the distribution of the Pteropods more thoroughly and in a special publication, but after becoming acquainted with the work of MEISENHEIMER I have no reason to do so. The following is to be regarded as a supplement to that work.

On the expeditions with the "Thor" I have found the following species of Pteropods in the northern part of the Atlantic:

Clione limacina (PHIPPS) MÖRCH (= *C. borealis* (PALL), *Limacina helicina* (PHIPPS) GUÉR.-MÉN., (= *L. arc-*

[1] This species has been found at all Danish quarterly stations between Iceland and the Færoes, but at the southern and most Atlantic (especially St. 7) only at great depths. Here it follows the cold water, which at the bottom passes over the Færoe-Iceland ridge from the north.

[2] About the plankton regions in the Norwegian Sea, see GRAN 1902, DAMAS 1905.

tica MÖL.), *Limacina retroversa* (FLEM.) GRAY (= *Limacina balea* MÖL., *Spirialis balea* and *retroversa* SARS), *Clio pyramidata* LIN. (= *Hyalaea pyramidata* d'ORB., *Cleodora pyramidata* SOUL.).

To these we must further add the following rarer species, of which according to BOAS and MEISENHEIMER all may also be found in the northern part of the Atlantic:

Clio falcata PFEFFER, *Clio cuspidata* BOSC., *Pneumodermopsis ciliata* GEG. (= *Dexiobranchaea ciliata* BOAS).

Of all these species two are according to MEISENHEIMER arctic, viz. *Limacina helicina* and *Clione limacina*, the latter however not exclusively. One species, *Limacina retroversa*, is characteristic for the transition-territory between arctic and warm, circumtropical current-territories. The other species are natives of tropical regions and from there spread towards the north.

These statements of MEISENHEIMER's correspond on the whole with my own observations which are briefly stated below. I may begin with the most arctic species.

Limacina helicina (see chart fig. 5) is exclusively a cold water species. GRAN (1902) considers it an arctic main form just as *Ceratium arcticum*, and according to BOAS and MEISENHEIMER its distribution in circumpolar (see MEISENHEIMER's chart).

Round Iceland it is only found at the north and east coasts and in the northern part of the Denmark Straits. In the latter it was found in numbers in June 1904 (see chart) at a depth of ca. 50—100 m, but not at the surface, and just at this station the upper water-strata were warm, of Atlantic origin, while there was cold polar water deeper down. In correspondence with this numbers of *Limacina retroversa* appeared at this station. Strangely enough the two species were found in the same water-strata, which were warm and salt (more than 35 ‰ salinity and 6° C.). The condition here changed from one day to the other, cold and warm water alternating (see p. 38).

Limacina helicina has been found at the north coast of Iceland in 1903, 1904 and 1905, in 1903 but in small numbers, in 1904 in great numbers together with many *L. retroversa*, in water originating from a mixture of the warm Irminger Current from the west and the cold arctic water from the north.

In 1905 *L. helicina* was found along the north and east coasts in great numbers and unmixed. At Eystra Horn, at the south-eastern corner of Iceland, just where the Arctic and the Atlantic waters meet, it was found together with *L. retroversa*, while further south it was wanting.

It may serve as an explanation of the difference between 1904 and 1905, that the polar ice in June and July 1905 lay all round the North Cape and blocked up the passage for the eastward running Irminger Current, while the same months in 1904 were free from ice.

Clione limacina (see chart fig. 6). This species GRAN has described (1902) as arctic like the foregoing. BOAS and MEISENHEIMER describe it indeed as arctic, but they both state that it is distributed far southwards in the Atlantic. BOAS gives Lat. 50° N. as its approximate southern boundary. According to MEISENHEIMER it may appear at Lat. 35° N.

Its distribution at Iceland and in the northern part of the Atlantic may be seen from the chart fig. 6, which shows that it is found in the cold polar water to the north of Iceland and in the warm Atlantic water to the south, as stated by SCHMIDT (1904). He also emphasizes that in the Atlantic water south of Iceland *Clione* is oceanic, ordinarily not found together with the neritic young cod but in company with the oceanic young of Sebastes, whereas in the cold water at North Iceland *Clione* is or may be neritic, to be found even in the fjords. The same result has been attained by DAMAS and KOEFOED. Thus, in the arctic sea between Spitzberg and Greenland *Clione* was found neritic, in the Norwegian Sea oceanic, occurring after the month of July. MASSY speaks of a number of places round Ireland where it has been caught.

According to my experience *Clione* is more frequent in the Atlantic water than in the Arctic. Both south of Iceland and in the eastern warm part of the Denmark Straits the "Thor" has often

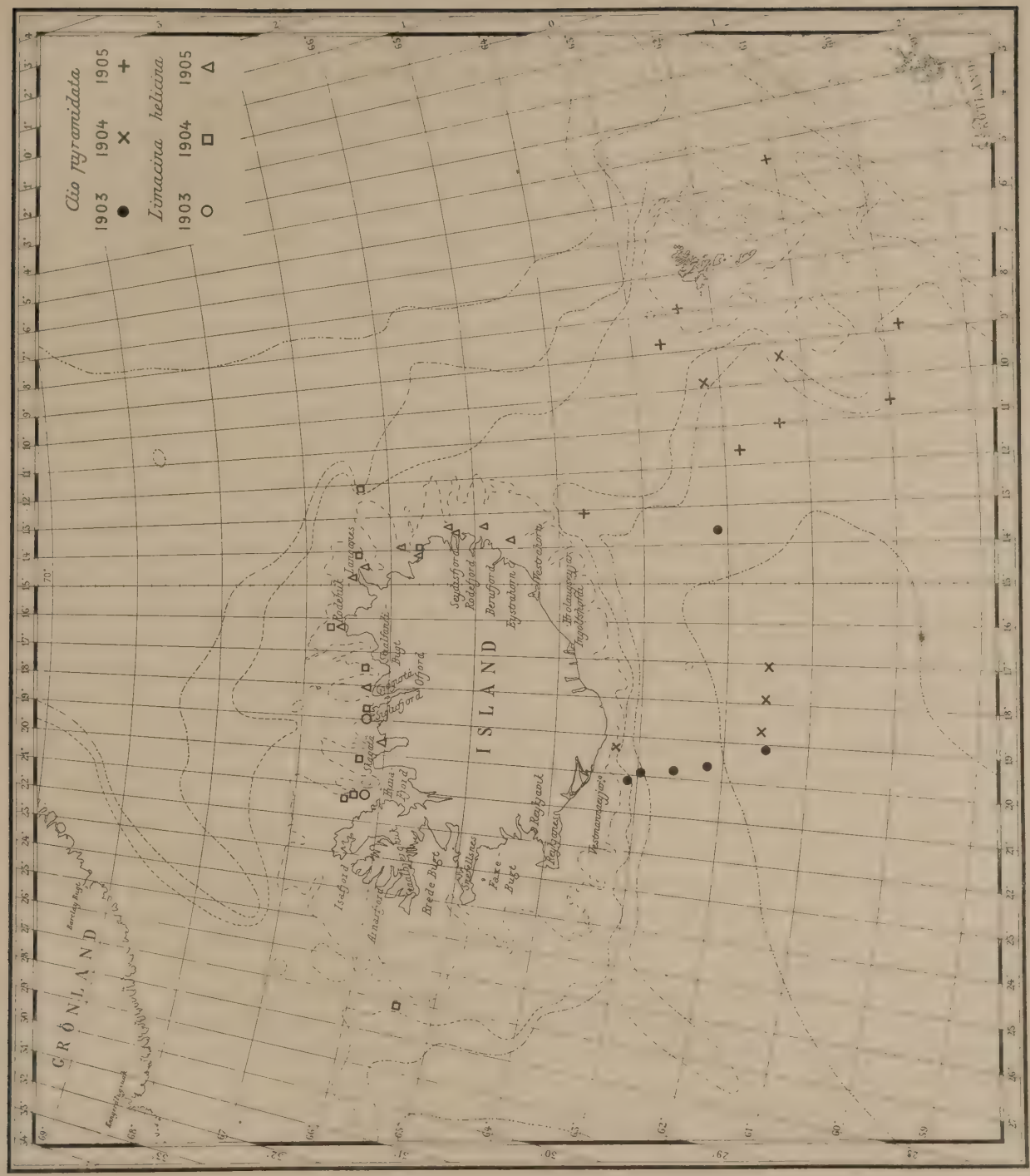
Clio pyramidata
1903 1904 1905
Limacina helicina
1903 1904 1905
GRÖNLAND
ISLAND

Fig. 5.

found it in great numbers, and, as will be seen from the chart, at nearly all pelagic stations. As already mentioned by MEISENHEIMER it is smaller in the warm water than in the cold. Of warm-water specimens I have even seen a great many quite small specimens, the young less than 1 cm long, and both to the south of Iceland and west of the British Isles as far as south of Ireland. JENSEN, JOHANSEN and LEVINSEN (1903) also speak of the young from the Skager Rak. From this it is evident that *Clione limacina* propagates in the Atlantic. That it propagates also in arctic water is mentioned by BOAS, DAMAS & KOEFOED and others. DAMAS and KOEFOED give a very interesting hypothetical explanation of the fact that *Clione* seems to be more neritic in arctic waters but oceanic in warm waters. These authors suggest that *Clione* in arctic regions propagates in shallow water, fixing the eggs on the bottom, but in warmer waters goes into greater depths to spawn, and that the animal thus, coming up again from the bottom, in the one case is to be found in the vicinity of land, in the other in the open sea.

As to the occurrence of *Clione* in the cold water the material from "Thor" is too small to permit any control over the statements of DAMAS and KOEFOED. In the atlantic water on the other hand we have found *Clione* a mainly oceanic species, as already mentioned. In the open Norwegian Sea *Clione* is said not to occur regularly before the month of July. In the Atlantic south of Iceland it is not so, there *Clione* is to be found already in May.

In accordance with the statements given above I conclude that *Clione* exists in two separate biological and geographical races, an arctic and a boreal one differring in outward appearance by their different size.

Clione is a true plankton organism, found in the open sea where it lives on smaller plankton organisms. The "Thor" has most often fished it at a depth of 10—50 m, but it may live both in the surface itself and far down in deep water (ca. 600 m., cf. MASSY). One of the places where I have seen it in greatest numbers is south of Iceland, at Lat. 62° 44′ N., Long. 20° 44′ W.

Here in July 1904 *Clione* and *Limacina retroversa* besides some medusæ were frequent organisms of the macroplankton at and near the surface (conf. p. 35). And just here at least eight large whales were playing about on the surface of the water. But Clione is also an excellent food for the plankton whales, just as according to MASSY it is common food for the herring and mackerel.

In the above statement no regard has been paid to *Clione gracilis* MASSY (1909), which has been described from the waters west of Ireland from deep water. It is only known in few specimens, and as far as I remember and can judge from description and figure, I have not had this species before me.

Limacina retroversa (see chart fig. 7) is according to the statements in the literature a North Atlantic species (see especially MEISENHEIMER's chart). According to JENSEN, JOHANSEN and LEVINSEN it also goes into the Kattegat, and according to MASSY it is very frequent at the Irish coasts. Its distribution round Iceland may be seen from the chart. Especially to the south and west of Iceland it is very frequent; the "Thor" has caught it here in thousands; in the hauls of the young fish trawl it appeared like so much gravel at the bottom.

With regard to the appearance of the species in the mixed water of the Irminger Current to the north of Iceland I can give the following information. In the first days of June 1904 it was wanting at the eastern part of the north coast, but it was found at the western part of the north coast at Long. 19° 22′ W. (see pag. 39).

In the last half of July it was still absent at the eastern part of the north coast, but at the end of August the "Thor" found it — together with *L. helicina* — not only in numbers at several places at the eastern and western north coast — though with long intervals where it was not found — but also far to the east of Lánganes, at about 12° Long. W. That *L. retroversa* was found so far out in the cold East Icelandic Polar Current is a consequence of the presence of a water-stratum of partly Atlantic origin,

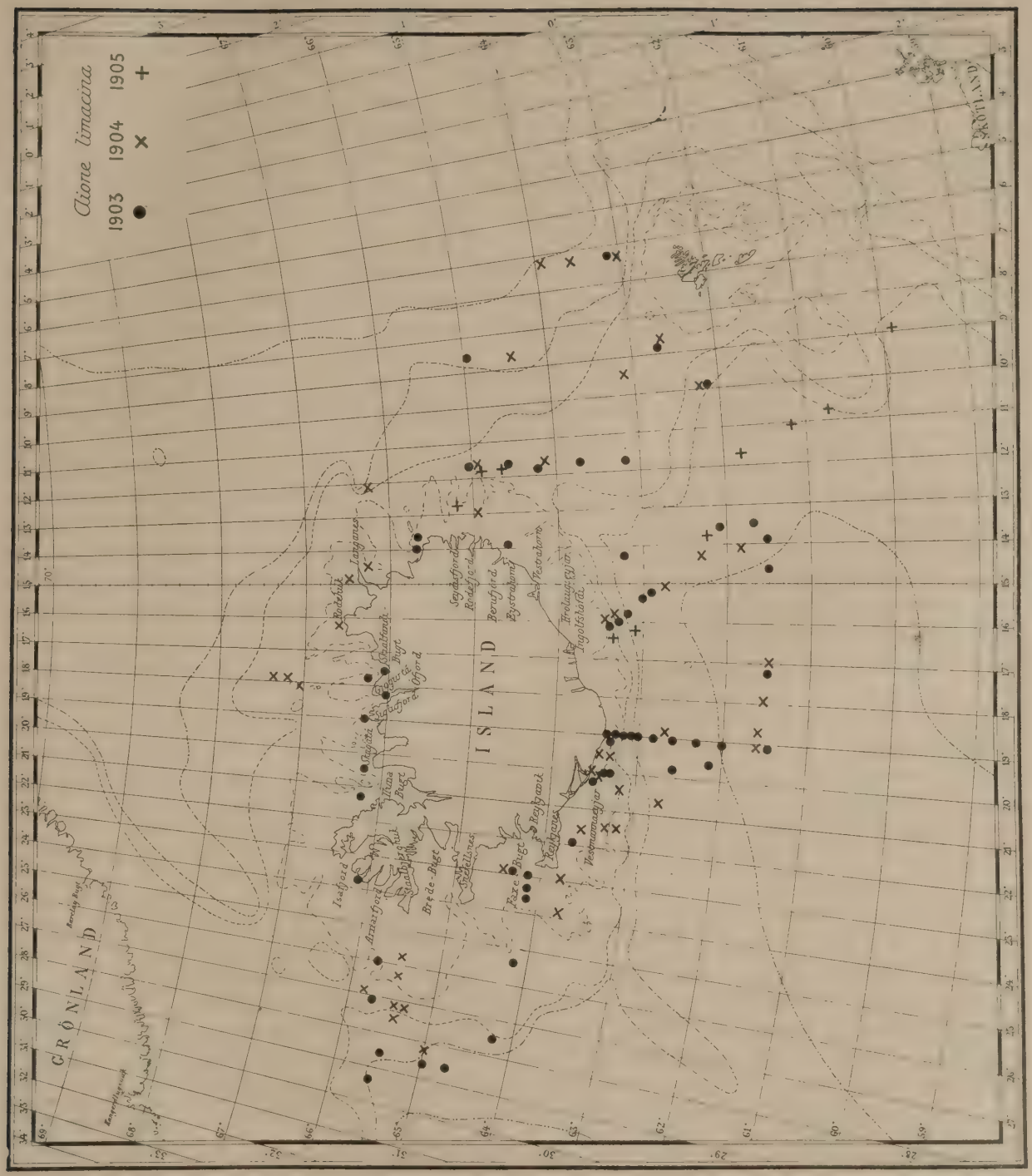

Fig. 6.

which has been carried so far along the north coast of Iceland by the Irminger Current. There are also several conditions in the plankton which prove its western origin (see pag. 39).

L. retroversa like the above-mentioned species is a real pelagic organism. It lives on organisms in the microplankton (Boas), and according to Scott (cit. from Massy) it is at times an important food for the herring and mackerel. I have found it in great numbers from the surface of the sea to a depth of ca. 70 m or more, both in the day and at night. It is probable that like many other organisms of the macroplankton it may disappear from the surface in the day. This I have not found to be the case at Iceland, but there the difference between day and night is indeed but slight in the summer (cf. p. 38 beneath.). At Iceland it must then be able to stand the daylight. It lives also however on organisms which are dependent on the daylight.

Clio pyramidata (see chart fig. 5) belongs to the tropical species which are distributed some way towards the north. According to Meisenheimer's chart it occurs right down to the Equator and is distributed as far as north of Lat. 60° to the south of Iceland as well as in the southern part of the Davis Straits.

The Chart shows that it may go close to the coast of Iceland and that it has principally been found in pure Atlantic water, frequently in large numbers, more rarely in territories with mixed water and never in arctic water.

The other three species mentioned by Meisenheimer which may occur in the north, viz: *Clio falcata* and *cuspidata* and *Pneumodermopsis ciliata*, I have not found in this part of the northern Atlantic. I have however caught all three of them from the "Thor" in the Atlantic round the British Isles and in the Bay of Biscay. I may further add two species, viz: *Cymbulia Peronii*, caught in the Bay of Biscay as far north as between the Hebrides and Rockall, and *Hyalaea* (*Diacria*) *trispinosa* from the Bay of Biscay, not caught further north than to the west of Dingle Bay in Ireland. According to Massy's statements this species has been found as far as ca. Lat. 55° N.

Concerning the purely southern Pteropods taken in the Bay of Biscay I hope to publish something later.

According to Massy the following species of Pteropods have further been found to the north of the Porcupine Bank, the large bank which is situated to the west of Ireland, and which seems to be the northern boundary for many southern species: *Limacina helicoides* Jeffr., *Peraclis reticulata* d'Orb., *Peraclis triacantha* (Fish.), *Thliptodon Gegenbauri* Boas., *Thliptodon diaphanus* Meis.

None of these species has been found north of ca. Lat. 55° N.

M. Euphausidae and Hyperinae.

The species belonging to the Euphausidæ are of great importance, since on account of their, for plankton animals, considerable size and their number they form, as is well known, an important food for fish and whales (see J. Schmidt 1904, Hjort 1902). I have found the following species at Iceland: *Boreophausia* (*Rhoda*) *inermis* (Krøyer), *Boreophausia* (*Rhoda*) *Raschii* (Sars), *Thysanoëssa neglecta* (Krøyer), *Thysanoëssa longicaudata* (Krøyer), *Nyctiphanes norvegicus* (Sars), (*Meganyctiphanes* Holt & Tatt.).

All have pelagic eggs, and in spring the surface of the sea is full of these eggs (Sars 1898, Gran 1902), but only in the warmer regions. Of the last fact we may convince ourselves by means of the data in the "Bulletin des résultats" as far as the northern Atlantic in May is concerned. Especially the Norwegian investigations in May 1903 show this clearly. In the eastern warm part of the Norwegian Sea there were quantities of eggs, but in the western cold part they were wanting. At the stations which

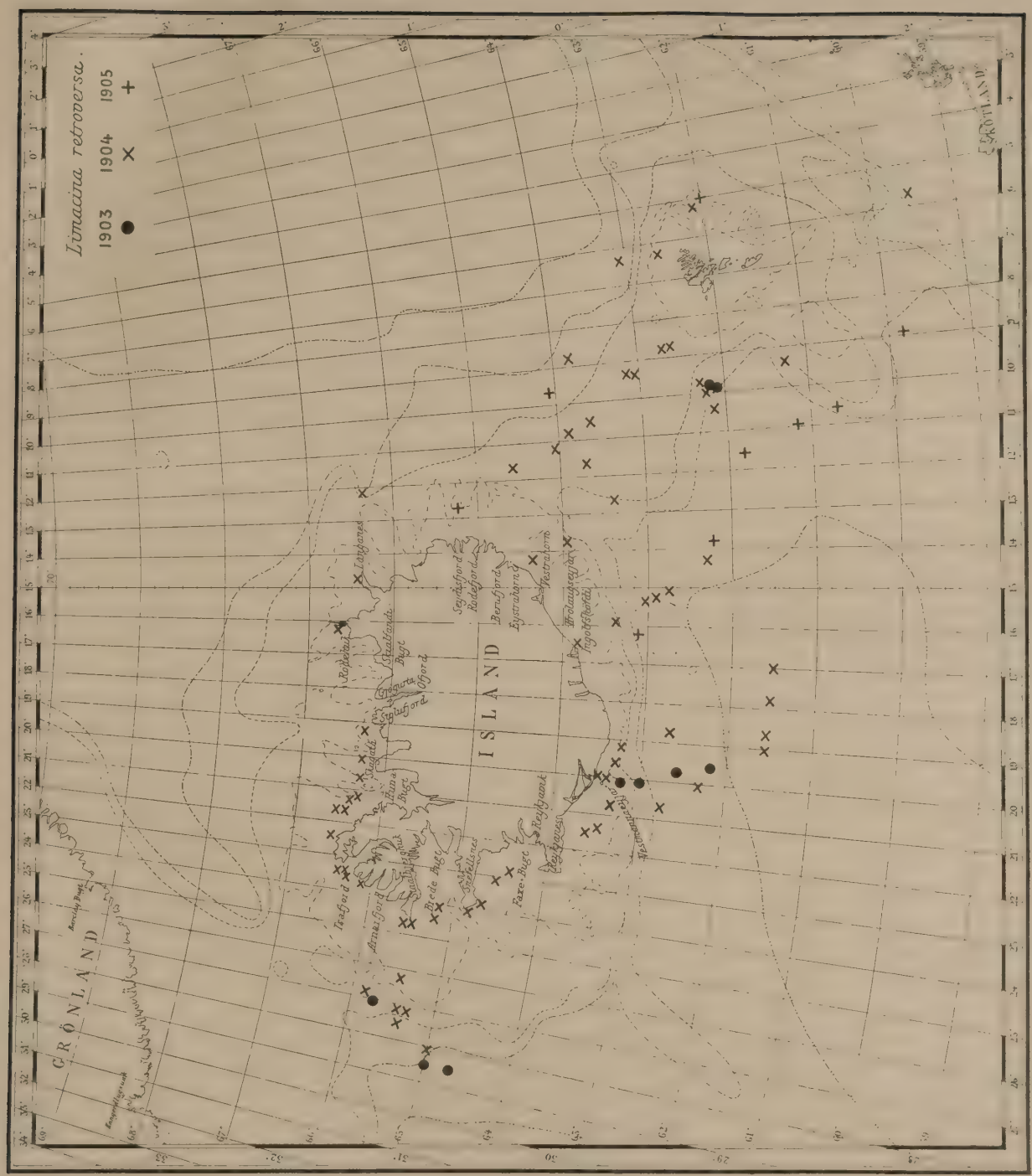
Limacina retroversa.
1903
1904
1905
GRÖNLAND
ISLAND
FÆRØERNE

Fig. 7.

had eggs the surface-temperature was more than 6·8°, while 5° was the highest temperature for the stations without eggs. The facts are somewhat similar from the Danish stations in May between the Færoes and Iceland. The northern cold stations have few or no eggs of Euphausidæ, while the warm stations have a great many. From this it is evident that the Euphausidæ propagate in warm water and not in cold. The Charts will give a notion of the distribution of the species.

Boreophausia inermis (see chart fig. 8). The Chart shows that this species is most distributed to the north of Iceland and in the cold water north of the Iceland-Færoe ridge. From this rule there are but two exceptions where it has been found in places close to each other at the western south coast of Iceland. As this is so different from the other information on this species I have quite naturally suspected that the animals have been wrongly determined, and I dare not exclude this possibility, although the species is not difficult to recognize. The first time it was found was in July, when there was a considerable number of large specimens at a depth of ca. 40 m, the other time some specimens were found at the end of August at a depth of ca. 60 m.

To the north of Iceland the "Thor" found *Boreophausia inermis* in 1904 at nearly all the stations which were examined at the beginning of June, while the water was still cold (3—5° C., see Nielsen 1905, Sect. II). At the end of July when only the eastern north coast and the waters northwards past Grimsö were examined, the species was only found at the northern stations at a depth of ca. 200—500 m, where the water was cold (Nielsen 1905, Sect. VI). And the same was the case at ca. 12° Lat. V. in the East Icelandic Polar Current.

At the end of August when the entire north coast of Iceland was examined *Boreophausia inermis* was wanting everywhere except off the Skagatá and in the Bay of Huna, and just here and not at the rest of the north coast there was polar water (Nielsen 1905, Sect. VIII).

In the northern part of the Denmark Straits the species has been found in June and between Iceland and the Færoes at different times of the year but only in cold water or mixed water, which may be seen from the chart. At the east coast of Iceland it has been found at many places.

On the whole *Boreophausia inermis* seems at Iceland to be a species which belongs to the cold polar water, but which may also be found in territories where this is mixed with warm Atlantic water. The information we have from the "Bulletin des résultats" on the Norwegian Sea possibly allow of an extension of this opinion also to the latter sea. Especially from February 1903 we find several statements. Two of the places where it is stated to have appeared are however in the warm Gulf Stream territory, viz: 61° 07′ N., 4°·12′ E. and 63°·16′ N., 0°·35′ E. The other places for its appearance — where *Nyctiphanes* was also found — were in the cold part of the Norwegian Sea or possibly in the territory of mixed water between warm and cold water.

According to the "Bulletin" the species is said to have been taken in the northern part of the North Sea and in the Channel. Holt and Tattersall state that it is frequent round Ireland at small depths. Here it is said to be an important food for mackerel and herring. According to H. J. Hansen it has been found at the coasts of Norway, West Greenland, East Greenland, Jan Mayen and Franz Joseph'sland as well as in the Kara Sea.

Boreophausia inermis has been found over depths of more than 1000 m, going as far down as ca. 450 m. In the night it often comes higher up in the water, but also in the day it may at times be found in the surface. It lives on organisms of the microplankton, of which fact I have convinced myself. I have found its stomach stuffed with *Asterionella japonica* and besides pieces of *Chaetoceras*, *Coscinodiscus* and Crustacea. *Boreophausia*'s wanderings to the surface are thus probably wanderings for food.

Boreophausia Raschi (se chart fig. 9). The distribution of this species may be seen from the chart. It is rather rare as far as I have seen, and it has only been found at a few places near the

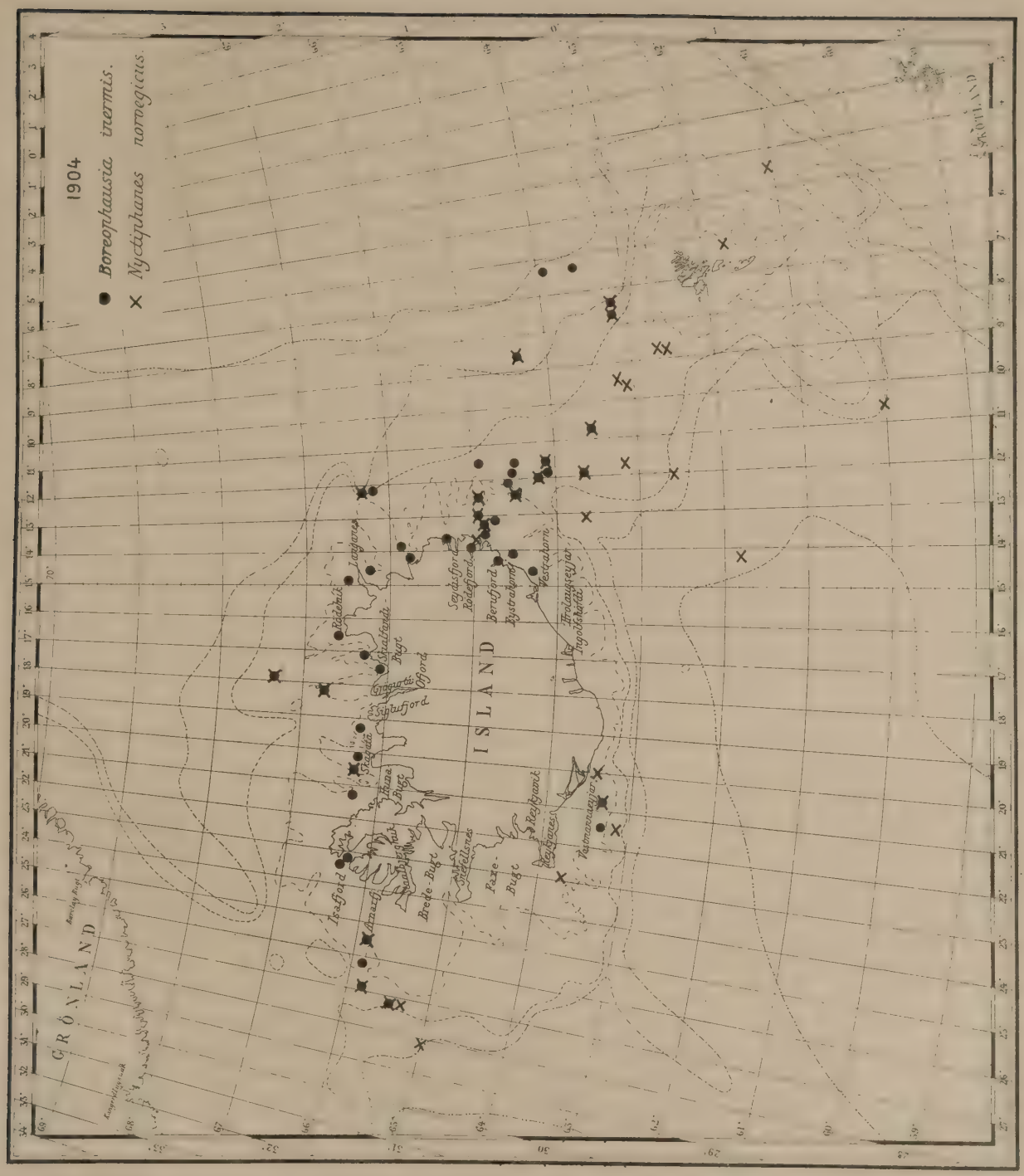
1904
Boreophausia inermis.
Nyctiphanes norvegicus.
GRÓNLAND
ISLAND
SKOTLAND
Ísafjord
Arnarfjord
Breide-Bugt
Patre-Bugt
Reykjanes
Faxe-Bugt
Skjálfandi
Eyjafjord
Seydisfjord
Berufjord
Austerhorn
Vestrahorn
Hvalsey
Ingolfshöfdi

Fig. 8.

coast at depths of less than 200 m, only once (south of Iceland) at 1000 m. It has been fished from a depth of 80 m to the surface. Judging from the chart it is most probably a species which lives both in warm and in cold water. This species has also been found in the northern part of the North Sea ("Bulletin"), in the Norwegian channel and in the Færoe-Shetland channel. It is not mentioned in Holt & Tattersall's list of Schizopods. It is stated to have been found at the coasts of Norway, in the Davis Straits and at the coast of West Greenland (H. J. Hansen).

Thysanoëssa longicaudata (see chart fig. 9) is probably the most frequent of the Euphausidæ at Iceland. According to my experience it is the species which lives nearest the surface. That is perhaps the reason why it is caught so frequently. As chart 9 shows it has been found at a number of stations to the south of the island, in the Denmark Straits and between the Færoes and Iceland, at the last-mentioned also at the cold-water stations and at one of them both in May and in August. To the north of Iceland it has also been taken at many stations, to the east of Rødehuk in April, at Lánganes in June, at several places in June, but it does not become frequent till August. It is thus partly in contrast to *Boreophausia inermis*, which is only frequent in the earlier part of the year, when the influence of the Irminger Current is still but slight or none. *Thysanoëssa longicaudata* has been found in April at the mouth of the Seydisfjord and at Papey, both on the east coast. To the east of Iceland it has however been taken in greatest numbers in August. According to the "Bulletin" it has been taken by the Norwegians in August 1903 in the cold part of the Norwegian Sea, and besides in the northern part of the North Sea and in the Skager Rak. According to H. J. Hansen it is found at Norway, Jan Mayen and Spitzbergen (further north to Lat. 84½° N.), at Franz Joseph's Land and in the Davis Straits (see also Damas & Koefoed). According to these data we must designate *Thysanoëssa longicaudata* as a species belonging both to warm and cold water. Holt & Tattersall state it to be frequent at Ireland, (though to a slight degree different), and call it "a truly oceanic species of the North and Arctic Atlantic".

I have taken it over depths of more than 2000 m, going as far down as ca. 900 m. It is most frequently caught at ca. 50 m below the surface. It often goes right up to the surface both in the day and in the night.

Thysanoëssa neglecta (see chart fig. 9) is more rare than the preceding species, and it has not been taken at many stations. The places for its capture marked out on chart 9 seem to show that it is a cold-water species; it was found already in June along the north coast, but also in July and August. According to the "Bulletin" it does not seem to be rare in the northern part of the North Sea. According to H. J. Hansen it has been found at West Greenland, Spitzbergen as well as at the coast of Norway. Holt & Tattersall mention it from the Irish coast, where it is said to be non-oceanic. It has been found at the surface only at night, in the day it seems to stay near or at the bottom of the sea.

At Iceland it has not been found over depths of more than 600 m, going as far down as ca. 460 m, but it may also appear at the surface.

Nyctiphanes norvegicus (see chart fig. 8) is a species which appears commonly right down to the Mediterranean where I myself caught it in numbers, and which goes as far north as to Spitzbergen and Jan Mayen (Holt & Tattersall). According to Damas and Koefoed it has been found abundantly in the surface of the Greenland Sea, near Jan Mayen, in the month of February. Here, in summer time, the animals seem to leave the warmer surface-layers. Chart 8 shows the stations where it has been taken by the "Thor". They are rather few, probably because Nyctiphanes generally stays rather deep down and therefore as a rule is not caught at stations where particularly deep hauls are not made. Most deep hauls were made between Iceland and the Færoes, and here it has also been found most frequently

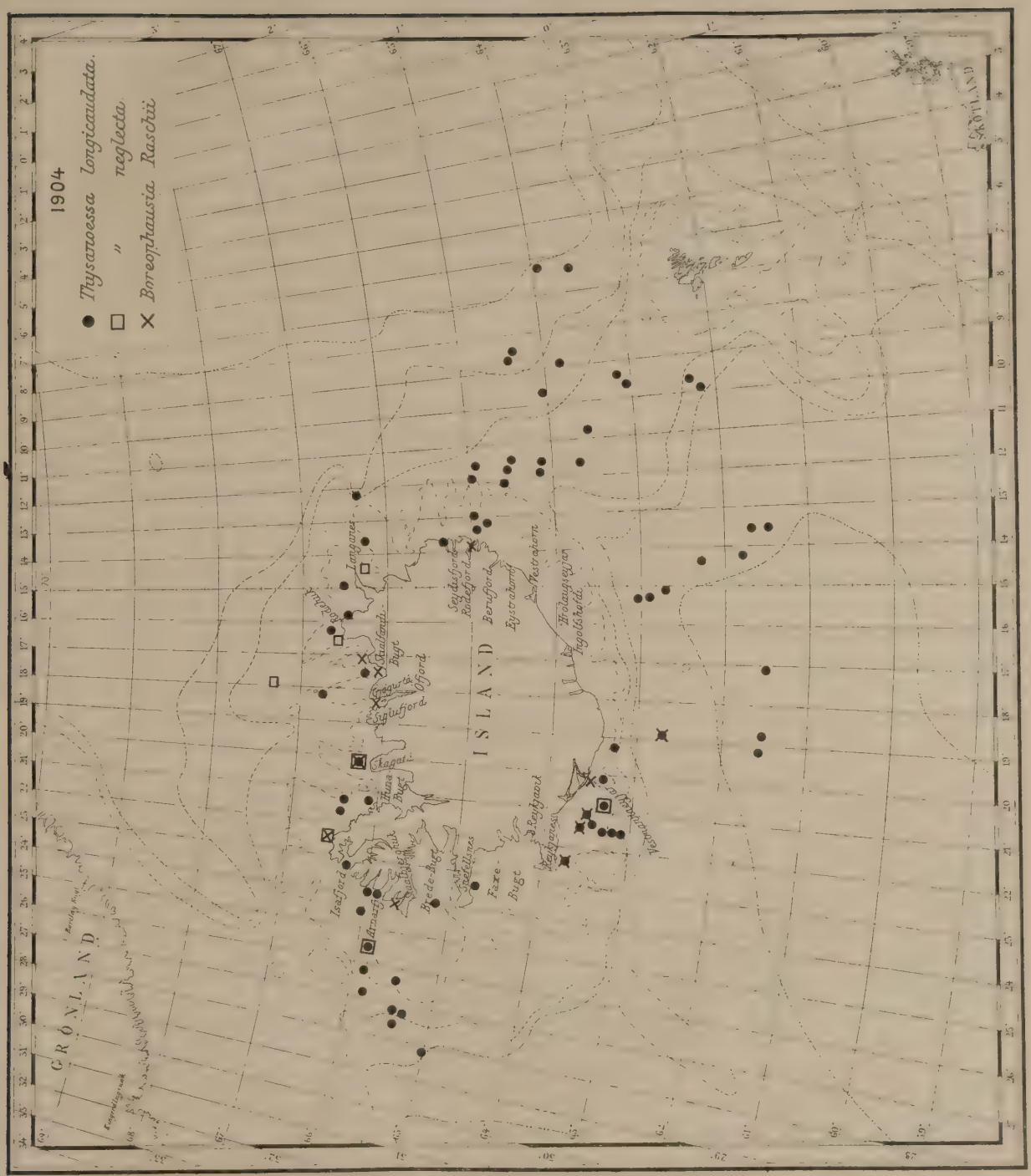
1904
● Thysanoessa longicaudata.
□ „ neglecta.
× Boreophausia Raschii
GRØNLAND
ISLAND
Langanæs
Sejdisfjord
Rudefjord
Berufjord
Eystrahorn
Austrahorn
Hvalnesfjord
Hvalnesvik
Ingolfshöfdi
Reydarfjord
Faxe-Bugt
Breide-Bugt
Isafjord
Skagafjord
Eyjafjord
Skjalfandi-Bugt
Langanæs

Fig. 9.

At the north coast of Iceland it has only been found in July and August, and far to the east of Lánganes in August, — at the station where a water-layer originating from the Irminger Current has been detected by NIELSEN (1905). In August it has moreover been found at a cold-water station (Da Atl 10) in considerable numbers.

At all these cold stations — also the two most northern to the north of Iceland — *Nyctiphanes* appears together with *Boreophausia inermis*, which, as stated above, was also the case in February 1903 at two Norwegian stations in the Norwegian Sea (64° 39′ N., 3° 06′ W. and 69° 37′ N., 6° 45′ W.). With regard to the northern stations to the north of Iceland NIELSEN has proved (1905, Sect. VI), that even the most northern is still influenced by the Irminger Current. Thus, we are here still in a territory with mixed water. But whether the same may be said of the just mentioned stations in the Norwegian Sea is very doubtful. At North Siberia, Spitzbergen and Jan Mayen — to which places *Nyctiphanes* according to HOLT & TATTERSALL is distributed — the Atlantic water must be so mixed, if there be any at all, that we are justified in saying that *Nyctiphanes* lives in arctic cold water as well as in Atlantic warm water. According to H. J. HANSEN it has been found as far north as at Lat. 81° N., but it is said not to have been taken in the Davis Straits or Baffins Bay.

With regard to food the following information on Nyctiphanes norvegicus can be given.

I have found three specimens from the Denmark Straits with the stomachs full of *Asterionella japonica* and some *Cyttarocylis denticulata, Thalassiosira, Chaetoceras, Dinophysis acuminata.*

Of four specimens taken to the east of Lánganes two contained recognizable fragments of *Globigerina,* the one remains of Crustacea as well, while the two others principally contained remains of Crustacea; a bit of an antenna of Calanus could be recognized with tolerable certainty, and one had *Ceratium arcticum* and *Peridinium ovatum* as well.

Thus, *Nyctiphanes* like *Boreophausia* feeds on microplankton, and when it approaches the surface, we may suppose that it does so to seek food.

According to HOLT & TATTERSALL it cannot live at a depth of more than 500 fathoms (= ca. 900 m) and is at times frequent at a depth of 60—20 fathoms (ca. 100—35 m). These figures are in agreement with my own observations. I have found it at a depth of down to 700 m, but most frequently at a depth of a little more than 100 m, often far out at sea, over depths of more than 2000 m.

HOLT & TATTERSALL state that at small depths it may live some time at the bottom.

Of these species *Boreophausia inermis* seems to be the most northern, *Nyctiphanes* the most southern, i. e. mostly confined to cold and warm water respectively. But as we have seen, none of the species are strict in their claims on the surroundings. All of them may at any rate go from the water-layers in which they really belong into mixed territories with different hydrographical conditions. If on closer investigations, which are necessary, it proves correct that the Euphausidæ only spawn in warm Atlantic water (cf. pag. 46), we have here interesting examples of the fact, that different claims on the surroundings may be made for propagation than for the maintenance of life. (Cf. SCHMIDT 1909, p. 151, where some such thing is proved on the part of *Gadus Poutassou*).

The above description of the distribution of the Euphausidæ species round Iceland may justly be called sketch-like. But on account of the importance of these animals in the economy of the sea I have considered it right to publish the material, which has been procured from expeditions sent out for other purposes. We must hope for some opportunity to make special investigations on the distribution, propagation and the whole biology of the Euphausidæ.

Another group of larger plankton-animals, which are of importance, are the Hyperidæ. Of these I have given my attention to the following four species: *Euthemisto libellula* (MANDT), *Euthemisto compressa* (GOËS), *Euthemisto bispinosa* (BOECK), *Parathemisto oblivia* (KRØYER).

I may briefly sketch the distribution of these species.

Euthemisto libellula is, as already stated by GRAN (1902), an Arctic species. In our territory it has been found only to the north and east of Iceland and at cold-water stations to the north of the Iceland-Færoe ridge.

The other species have all been found both in Atlantic and in Arctic water round Iceland, separately or sometimes all three together.

Euthemisto compressa and *bispinosa* are perhaps of a somewhat "colder" character than *Parathemisto*, as they are found more frequently than the latter at the north coast at the beginning of the year. *Parathemisto* is by far the most frequent.

I have not made use of the data in the "Bulletin", as the determinations are hardly certain; with regard to the Danish material I know that they are not.

RESUMÉ.

1. The neritic plankton of South Iceland is characterized in spring by the diatom *Asterionella japonica*. This plankton, its distribution and its hydrographical condition is described. Towards the south it goes seawards in streaks, and also towards the east it will sometimes drift off from land, which is in agreement with J. N. NIELSEN's view, that the current at South Iceland has an eastern and not a western direction (Chap. A).

From the distribution of Asterionella in Icelandic waters and elsewhere the conclusion is drawn that microplankton organisms are transported by sea currents only within limited areas (p. 8).

2. The Asterionella plankton is succeeded in the summer by a Dinoflagellate plankton. In this we find more copepods than in the diatom planktom. In the autumn there is a faint second diatom maximum together with the Dinoflagellates.

3. The Asterionella plankton drifts with the Irminger Current along the west coast of Iceland, but here it generally keeps outside (to the west of) the real coast-plankton (Chap. B).

4. This, the neritic plankton of the west coast is characterized in spring by *Thalassiosira*. This first diatom maximum is succeeded in July by Dinoflagellate plankton. A second diatom maximum (*Rhizosolenia*) in the autumn mixes its organisms with the Dinoflagellates (Chap. B).

5. The different fjords in the north-western part of the land have each their own plankton. In some of them the neritic plankton of the spring will last a long time after it has disappeared outside the fjords (Chap. B).

6. The distribution of the *Ceratium*-species is described (pag. 6 and chart fig. 2). *C. tripos* is mostly found at the south coast only. In the plankton, which drifts along the west coast, it is succeeded by *C. lineatum*, which according to LOHMANN is said to be able to arise from *C. tripos*. *C. lineatum* has a maximum at the western north coast, where it seems to copulate. A similar case of the distribution of these two species is found in the Denmark Strait.

C. furca and *intermedium* are southern species, *C. arcticum* a northern. *C. longipes* is found together with *C. arcticum*, but also in mixed territories.

7. At the north coast of Iceland the plankton alternates in the course of the summer in the following way:

a. First diatom maximum (*Thalassiosira*), constant and distinct only at the western part of the coast.

b. Second diatom maximum (*Chaetoceras decipiens, Rhizosolenia styliformis*) in July and August. May be mixed with

c. Dinoflagellate plankton, in which *Ceratium longipes* is the most constant. *C. lineatum* is mostly found only at the western stations, *C. arcticum* not at the most western.

d. Third diatom maximum in October, formed at the western part of the coast by *Thalassiothrix*, at the eastern part by *Corethron* (Chap. C).

8. The plankton at the western part of the north coast is more like the plankton of the west coast, at the eastern part it is colder and more oceanic.

9. The difference in the plankton in 1904 and in 1905 may be brought in connection with the condition of the ice in the two years.

10. To the east of Lánganes, where NIELSEN has formerly proved the presence of water-strata originating from the north coast, plankton originating from the same place could also be traced.

11. At the southern part of the east coast, near the boundary towards the Atlantic water, the coast plankton of the spring is very extensive and lasts long. In August Dinoflagellates appear, in September—October a second diatom maximum (*Chaetoceras*). The plankton of the fjords is described (Chap. D).

12. In the Seydisfjord the water was for some days blood-red from a small Protozoon, *Mesodinium pulex* (Chap. D).

13. Investigations of the plankton in a fjord on the east coast, where two whale-stations were found, and comparison with the plankton in other, similar fjords without whale-stations, showed, that if the grease and dirt originating from the stations in any way influence the quantity of plankton, this influence goes towards an increase of the quantity. Of a decrease there can be no talk (Chap. D).

14. A comparison of the distribution of the microplankton organisms shows: that while some species are confined to the south coast only, there is a series of species which the south and the west coast have in common. The west coast has but one species to itself — whose centre of distribution is here — and likewise but one exclusive species is common for the west and the north coast. To the north coast only two small diatoms are restricted, while the north and the east coasts have a series of species in common. The division shows the two water-territories at Iceland: that of the south and west coasts and that of the north and east coasts. The latter as the colder excludes some species, which are found at the other coasts. Lastly we find a long series of species living at all the coasts (Chap. E).

15. The different oceanic plankton-communities round Iceland are briefly described. Among other things a mixed territory to the east of Cape Farewell is mentioned, in which southern oceanic and northern neritic plankton are mixed (Chap. I).

16. On a large submarine bank S. W. of the Færoes the plankton was richer and more neritic than in the surrounding water; the water on the bank was likewise colder and fresher. Here the diatom flora seems to last all through the summer. The peculiar hydrographical conditions indicate that the water is but slowly renewed. Vertical sea-currents at the edge help perhaps to create richer life (NATHANSOHN).

17. *Halosphaera viridis* extends in spring over the whole area of the North Atlantic until the coast of Iceland (p. 5).

18. The macroplankton in the seas round Iceland is described, especially with regard to the animals important as food for fish. Of these the *Euphausidae*, *Calanus finmarchicus* and the Pteropods are the most important. *Calanus* often appears in clouds and is wanting at other places. Many animals make vertical day and night wanderings. The plankton of the summer is rich in all the seas round Iceland. The fauna of the Denmark Straits is like that of the Atlantic, but it also contains cold-water species (*Calanus hyperboreus*). North-Iceland and East-Iceland have the same oceanic fauna, and under the coast the difference gradually disappears by the influence of the Irminger Current (Chaps. G—K).

19. Of the intermediate and bathypelagic fauna of the Atlantic information is given, based on the collections of the "Thor" (p. 36).

20. It is proved that Plankton-nets, which go down open, also fish while they are being let down. Vertical hauls with such nets are therefore not reliable (p. 36).

21. The distribution of the Pteropods round Iceland is described and charted. One species is Arctic, one is warm Atlantic, one is North Atlantic and is besides found in mixed water, and one is both Arctic and Atlantic (Chap. L).

22. The distribution of the Euphausidae round Iceland is described and charted. All the species live in different water-territories round Iceland, some (*Boreoph. inermis*) seem however to be more fond of cold than others. *Thysanoëssa longicaudata* is the one that lives nearest the surface of the sea, but like the other species it may be found at great depths. In all the seas round Iceland there are quantities of Euphausidae in the summer. They live on organisms of the microplankton (Chap. M).

23. The Euphausidae have pelagic eggs, which, according to what has hitherto been made known, are only found in the warm Atlantic water (Chap. M).

24. The distribution of some Hyperidae round Iceland is shortly described. *Euthemisto libellula* is the only stenotherm-stenohaline species, living only in Arctic water (Chap. M).

POSTSCRIPT.

After preparing the first sheets of this paper I have received Professor KOFOID's treatise on "Mutations of Ceratium" (Bul. Mus. comp. Zool. Harvard Coll. 52 N. 13).

Here the author suggests that the production of *Ceratium lineatum* by *C. tripos,* as described by LOHMANN, is better to be regarded as a mutation than as a seasonal, temporal variation, as which they were regarded by LOHMANN.

Of similar heteromorphic divisions KOFOID describes the following:

1. *Ceratium tripos* producing *C. californiense.*
2. *C. californiense* and *C. Ostenfeldii* (?) as cousin-cells in an incomplete chain.
3. KOFOID figures (tab. 4 fig. 6) a "mutating" chain of *C. californiense* and *C. Ehrenbergii* (?).

C. californiense and *C. Ehrenbergii* belong to the genus Biceratium, whereas *C. Ostenfeldii* belongs to Macroceratium and *C. tripos* to Tripoceratium, the latter two subgenera being new, established in this same paper.

Thus *C. californiense* should stand in genetic connection to species of three different subgenera. In my opinion this means that the importance of the structural features characterizing the subgenera has been exaggerated. When two "species" are found together in the same chain they cannot be said to belong to different subgenera but most be closely allied, — even if they are really species and the chain really mutating.

What the nature of the heteromorphic chains is, cannot be known at present, the fate of the heteromorphs being unknown.

I confess I am not perfectly convinced of the mutation in the chains, and perhaps it would be permissible to ask, what is the nature of *C. californiense*? This species reappears in all the "mutating" chains. Further it is a curious species, a Biceratium which sometimes "exhibits structural features which tend toward but does not attain the characteristics of the subgenus Macroceratium" (KOFOID p. 229). In

the original description this species is stated to be rare. Should not *C. californiense* be a transitional form of some kind or another? A deformity? Or a gamete?

As a whole it seems to me that the eminent author enlarges the conception of a mutation beyond the boundaries given to it hitherto, regarding as mutants new appearing forms without any evidence of their constancy.

To return to the connection of *C. lineatum* with *C. tripos*, of which I have spoken in the present paper, I should be inclined to regard them with LOHMANN as forms, seasonal or occasional. Not intending to intervene in the discussion between LOHMANN and KOFOID I will only remark, that the statements given on p. 16 et seq. of the present paper seem to speak in favour of this view. No specimens of *C. tripos* are carried northwards with the Irminger Current, though there are plenty of them in the southern part of it. Probably they must all produce *C. lineatum* or die. This is a state of things resembling the formation of flowers or spores by many plants and microorganisms when conditions grow bad. And as shown above it is possible that *C. lineatum* may be a gamete.

A short communication from Professor APSTEIN in Kiel on gemmation in Ceratium opens up a new prospect to our knowledge of the life of these interesting organisms. If *C. lata* really appears regularly by gemmation from *C. tripos*, all idea of mutation must be excluded at any rate for this form. Of *C. lineatum* nothing is said in APSTEIN's communication.

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